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## 9. First steps in understanding the economic principles of responsible research and innovation

*Miklós Lukovics, Benedek Nagy and Norbert Buzás*

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### INTRODUCTION

The area of responsible research and innovation (RRI) has gained credibility in scientific research and innovation policy in recent years. Uncertainty, ignorance and negative side-effects associated with innovation have created a school of thought that holds that research and innovation should be responsibility driven in terms of their impact on society, human beings and the environment. Academically, RRI is buttressed by a body of research: definitions, elements, key factors, dimensions and framework conditions have already been explored. Socio-technical integration has also been verified as a key element of the RRI framework. In spite of this, an explanation of the background of RRI using economic terms is still underrepresented in the multidisciplinary RRI framework.

In this chapter we use simple economic concepts from the neoclassical school to encourage non-economist scholars of responsible innovation to apply the economic way of thinking to this field. We demonstrate that the notion of responsibility can be grasped with tools familiar to the economist community and that this view is capable of offering ideas to promote responsible behavior in innovation. Instead of being technical, we want to be thought provoking and to facilitate RRI research with an economic foundation.

Alfred Marshall, a well-known economic theorist of the late nineteenth century, defines economics as the 'study of mankind in the ordinary business of life; it examines that part of individual and social action which is most closely connected with the attainment and use of the material requisites of wellbeing' (Marshall 1890 [1997], p. 1). Successful innovations have long contributed to human well-being and are undoubtedly the results of both individual efforts and social processes. Another widely quoted definition of economics is that it is 'a science which studies human behavior as a relationship between ends and scarce means which have alternative uses' (Robbins 1932, p. 15). The end can be an advancement of the frontiers of knowledge of humankind or solving a specific problem at hand, and the scarce means are effort, talent, time and money used during the innovation process. Economics does seem to have a connection to innovation.

Innovation generally comes down to achieving something that nobody has done before (such as launching the manufacture of a new product) or achieving something differently than anybody has done before (such as producing something more cost-efficiently). Science and innovation are an integral part of the structure of nearly all modern societies (Owen et al. 2013). Even though some innovations merely arise out of luck, most innovations stem from conscious search processes proceeding from somebody noticing a consumer wish ('how good it would be if there were a product that . . .') or a technical opportunity ('we could do that just as well in a different way . . .'). Innovators

however, are more often than not guided by the profit motive: an innovative product may well satisfy a consumer need and enhance the well-being of its users, but it will only be produced if it is profitable for the innovator. This is the reason we believe that economics is necessarily involved in matters of innovation. In this chapter, we look at whether the profit motive leads, or can lead, to an innovation process characterized by responsibility.

Innovative activity, however, often besides profit – which economists say is the primary goal of innovation – also generates side-effects that can be desirable in some cases, and not so much in other cases. The presence and consequences of side-effects in research and innovation have brought about a school of thought that maintains that science, research and innovation should be responsibility driven with regard to its overall effects on society, human beings and the environment (Guston 2004, 2008; Owen et al. 2013; von Schomberg 2013; Fisher and Maricle 2014; Pavie and Carthy 2014). Excellent academic studies provide a scholarly foundation for RRI: definitions, elements, keys, dimensions and framework conditions have all been investigated. Furthermore, the interdisciplinarity and multidisciplinary of the concept has also been highlighted (EC 2011; Owen et al. 2013; Sykes and Macnaghten 2013; von Schomberg 2013).

In contrast, a discussion of RRI from the point of view of economics is still under-represented in the multidisciplinary RRI framework. In this chapter, we address the lack of economic investigations in the area of RRI. Since this research is mostly done by non-economists, we are intent on simplifications and the use of such language and concepts that are easily understandable for a professional without solid economic training. Guided by the same intention, instead of providing a detailed overview of the numerous economic theories offering possible explanation for different RRI-related phenomena, we base our analysis on just one: neoclassical economic theory. We show a possible way that the concept of responsible innovation can be grasped with tools used in textbook economics without any of the complicated mathematics generally involved in scientific economics papers. Our aim is thus to show a new perspective from which researchers in the field can look at responsible innovation. We introduce the notion of externality to formalize the side-effects problem of responsible innovation. We are not suggesting that our analysis here is exhaustive, and concede that a deeper and broader analysis of the underlying economic forces and mechanisms is possible and desirable. We do think, however, that even the use of these simple concepts and economics reasoning can help in understanding why innovators might not behave responsibly and how the degree of responsible behavior could be increased among innovators. With our chapter it is also our aspiration to call the attention of economists to the area of RRI and thereby initiate a deeper investigation into it using multiple theoretical approaches.

We start our thinking about the economic background of responsible innovation with a definition of RRI by René von Schomberg:

Responsible Research and Innovation is a transparent, interactive process in which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of advances in our society). (Von Schomberg 2013, p. 63)

Based on this definition, we focus on the following questions from the point of view of economic theory:

- How can we formalize societal desirability in economic terms?
- Do the innovators have an incentive to act such that the outcome of innovation is societally desirable?
- How can transparency and interactivity enter the picture?

## AN ECONOMIC INTERPRETATION OF SOCIETAL DESIRABILITY

When we consider any innovation, it is easy to decide whether it is desirable from the viewpoint of any single person (whether a potential user of the innovation or not) or company<sup>1</sup> (the innovator itself or other companies). Users of the innovation probably find it desirable: they express this through their willingness to pay. They are willing to pay the price, since they derive more satisfaction from it than they have to pay, and their individual well-being increases. In the view of the innovator, it is also easy to decide on the desirability: if the innovation brings in more money than it costs, then it is desirable.

When we want to say something about well-being at the societal level, we have a bigger problem. In such cases, side-effects, or effects that spill over to non-users or companies other than the innovator involved, also have to be taken into account. The innovation might change their well-being in more indirect ways, for better or worse. Table 9.1 categorizes how an innovation can affect parties other than the producer of the innovation and its user, with some examples.

As seen from Marshall’s previous definition of economics, economists have been concerned with such concepts as human well-being, wealth and happiness from early on. Later a whole branch of economics, named welfare economics, evolved to study the welfare consequences of individual decisions. We do not want to give a concise overview of this area of inquiry but do borrow a few simple concepts from it to formulate the problems at hand.

Early classical economists offered a utilitarian answer to the problem of assessing effects on well-being at the societal level as early as the eighteenth century. Their answer

*Table 9.1 Examples of potential indirect effects of innovation*

		The party affected indirectly is	
		a non-user	another company
The indirect effect is	advantageous	Flow hive creates more relaxed conditions for bees, which thus pollinate farmers’ plants more frequently	Invention of cotton gin boosts the textile industry
	disadvantageous	Manhattan Project makes production of atomic bomb possible, leading to Hiroshima and Nagasaki attacks	Growing demand for aluminum for Apple and Samsung gadgets raises its price, thus re-arranging cost structure of battery industry

Source: Own compilation.

was the principle of utility, which provided a (theoretical) method to calculate whether any action will make a group of people affected better off or worse off overall, approving or disapproving of the action accordingly. Any action is deemed societally desirable according to the principle of utility and 'an action then may be said to be conformable to the principle of utility, or, for shortness sake, to utility (meaning with respect to the community at large) when the tendency it has to augment the happiness of the community is greater than any it has to diminish it' (Bentham 1781 [2000], p. 15). This meant taking individual well-beings and summing them up. This method, however, would necessitate the ability to provide a precise measurement of magnitudes and changes in individual well-being which is standard and comparable enough through individuals to allow summarization for a group of people. Since this proved not to be possible, economists had to look for a softer definition of well-being at a group level and with societal desirability.

The neoclassical school of economics generally uses the Pareto criterion coined by early twentieth-century economist Vilfredo Pareto. This criterion acknowledges that an interpersonal comparison of well-being is not possible in the above utilitarian sense. A Pareto improvement is an action that makes at least one person better off while making nobody worse off. If we cannot make any more Pareto improvements, we are Pareto efficient, in a state when anyone can only become better off if at least one person becomes worse off (Ehrgott 2012). For a society, more Pareto-efficient states can exist, and a society can move from a state that is not Pareto efficient to one possible efficient state through one improvement, and to another possible efficient state through another improvement. Any of these efficient states are better than the starting point (since we got there through a Pareto improvement, so nobody was hurt), but which of the two efficient states is better, let alone best, is difficult to say. The utilitarian approach above had a metric for this, but in the Pareto-approach society must evaluate the states according to their tastes. How a society forms its tastes would bring us into the realm of public choice and would have to include, in addition to efficiency, such notions as equity or fairness. If we define societally desirable as a Pareto improvement, then an innovation that positively and greatly affects a number of people and negatively affects even one person would not be considered societally desirable.

Starting from this characteristic of the Pareto criterion, Nicholas Kaldor and John Hicks proposed the compensation criterion: if some people are made worse off and others better off, but the winners could in theory compensate the losers, then the change is efficient. The change leads to a redistribution of well-being that is potentially a Pareto improvement (Kaldor 1939; Hicks 1939). The idea behind this is that society as a whole is made better off if the winners win more than the losers lose.

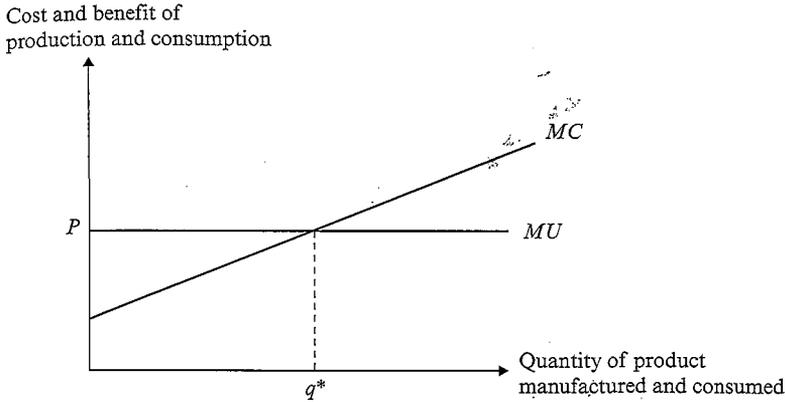
The last two interpretations are generally used in economic models whenever societal well-being is affected. All the approaches here include calculating with and summing up individual well-being, but while the first does this comparison in a direct way, the last two use the medium of money to make changes in the individual well-being commensurable. If we relate the different economic interpretations of societal desirability to innovation, then we could conclude that an innovation is societally desirable if the (Pareto-)Kaldor-Hicks criterion is fulfilled, that is, if the innovation generates altogether more benefits than costs to the parties affected.<sup>2</sup> Responsible innovators need to aim at innovations that satisfy this requirement. Our second question is about whether it can realistically be expected that innovators would or could find and realize those, and only those, innovations that satisfy this requirement.

## PRINCIPLES GOVERNING THE ACTIONS OF ECONOMIC ACTORS

First, we would like to review what economists consider to be the most important motive for economic actors and how this motive governs their decisions. For the sake of simplicity, we introduce the concepts for companies, and once the main logic is introduced we show how it can be used for innovators in general, whether they be companies, universities or research institutes. All these actors are just as limited in their choices by scarce resources with alternative uses as companies are when they make production decisions.

When economists think about motives among economic actors, they assume that economic actors are rational, which means that they are maximizing the net result of their action in everything they do. In some cases it means maximizing gain for a given effort, in other cases it means minimizing effort for a given gain. The term 'utility maximizer' is used for consumers because the economic model of consumption entails spending a given disposable income in the best, most useful or meaningful way. Companies are named 'profit maximizer' because they engage in production entailing revenues and costs in such a way as to get the maximum positive difference between the two. The rule for profit maximizing for companies is to do something (producing, selling or innovating) as long as their expected own additional benefits are higher than their own expected additional costs to the point where the two become equal. This calculation that companies are supposed to do before deciding how much to produce<sup>3</sup> is a cost-benefit analysis. We have to note four important points in this analysis. The first is that companies set costs and benefits against each other; they do not simply minimize costs or maximize revenue. The costs and benefits they consider, however, can also include non-monetary costs or benefits.<sup>4</sup> The second important point in the cost-benefit analysis is the word 'additional', meaning 'resulting from the decision'. This means that the costs and benefits that the actor considers must lie in the future, are of a kind that the actor can determine and will be affected by the actor's decision. The third point is that these future costs and benefits are by their very nature expected: the company cannot be entirely certain of their magnitude; it has to estimate them (which again takes up resources). The fourth and final point, which is most important as regards responsible innovation, is captured in the word 'own'. Companies can and will only consider those aspects of a decision that represent either costs or benefits directly or indirectly to them. There are no objective costs, only costs associated with decisions and persons. It is important to highlight that they are not doing this because they are selfish or even malevolent: mostly they are doing so because of a lack of information, because of their imperfect ability to detect and assess all the effects of their actions and because of the lack of an effective link between themselves and the often very round-about results of their decision.

As a start, let us examine a producer's standard decision of how much to produce. Assume that this producer is competitive, which means that it is too small relative to the whole market to be able to affect the market itself or the price of the product. Such a producer is also named 'price taker', since the price of the product is dictated by the market and the producer has to just simply take it as given and adjust its decision to that. This price is basically the willingness to pay on the part of the consumer, which in turn is directly related to how useful they feel an additional unit of the product is. This additional well-being gained by the consumer, named marginal utility (*MU*), is also the



Source: Own compilation based on Pindyck and Rubinfeld (2009).

Figure 9.1 Optimal choice of the profit-maximizing company

additional benefit of the producer: what the consumer is willing to pay is what the price-taking producer will get when producing and selling an additional unit of the product. Producing and bringing to market additional units of the product requires the firm to use resources (factors of production) and transform them to products. This will mean costs to the producer. The additional cost of producing a unit of the product is the marginal cost ( $MC$ ), and the more one wants to produce, the higher the marginal cost rises. We can see the two sides of the cost–benefit analysis in Figure 9.1.

As long as  $MU > MC$ , the producer is producing something more valuable than the resources it uses for production. The profit earned by the producer will increase with each additional unit of the product manufactured, sold and consumed. Production should be increased. Similarly when  $MU < MC$ , it is a sign that the value of the resources going into production is lower than the value of the final product: additional units produced and sold decrease the profit of the producer. Production should be decreased. The company will then choose to produce the exact quantity where  $MU = MC$ , which is the point of intersection of the two functions in the figure. This ( $q^*$ ) is the optimal or profit-maximizing quantity of the producer.

It can be shown that under the assumptions of a competitive industry and increasing marginal cost of production, the cost–benefit analysis of the producer not only leads to the production of a quantity of the product that is maximizing profit to the producer, but also to a quantity that is maximizing welfare to society as a whole. It is a Pareto-efficient outcome, which results if companies produce all those, and only those, units of the product that are at least as valuable to consumers as the resources going into their production. The centuries-old concept of the ‘invisible hand’ coined by Adam Smith (Smith 1776 [1999], p. 32) states that if everybody conducts his or her own cost–benefit analyses and decides accordingly, this will lead to higher welfare in society than if people were endeavoring to work out how to make decisions to increase society welfare.

Most decisions that people (or companies) make have unintended consequences on others that the decision-maker is not even aware of. A new innovative product might

be put to good uses that benefit society (and the innovator), but may also open up possibilities for misuses, causing harm to society.<sup>5</sup> In such cases the invisible hand may break down, and people minding their own business eventually do more harm than good even if unintentionally. How should a responsible innovator identify, anticipate and handle such situations?

## HOW MAY A COST–BENEFIT ANALYSIS LEAD TO A SOCIALLY INFERIOR OUTCOME?

Decisions generally affect other parties in addition to those that are involved in the original decision situation (producer and consumers, innovator and potential users or beneficiaries of the innovation and so on). We have already mentioned some examples in Table 9.1. For situations where decisions affect third, outside, parties, as well as the parties involved in a transaction without compensation, economists use the term ‘externality’. To formalize the side-effects problem of responsible innovation with the concepts of economics, we first have to understand how the presence of externalities affects the logic of the cost–benefit analysis or profit and welfare maximization.

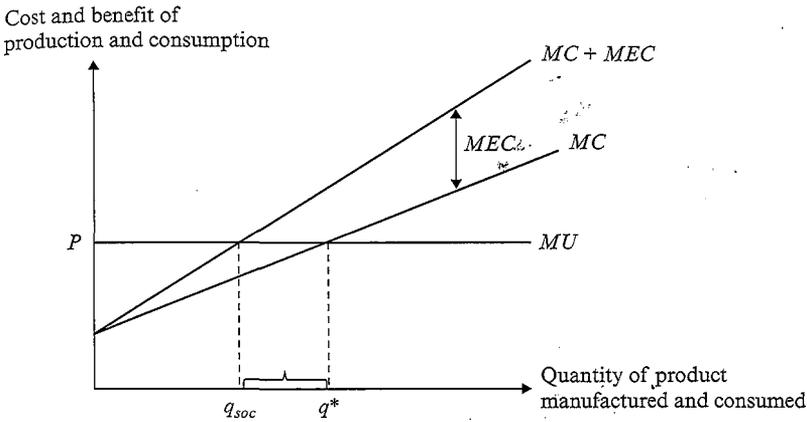
Continuing on the previous neoclassical model of optimal production, let us now suppose that the manufacture and/or consumption of the product has side-effects, that is, it can also impose costs on, or bring benefits to, other members of the society, not just to the producer and the consumer. Let any cost that is connected to the production and consumption of the product in question, borne by others than the producer and not compensated through the market, be called external cost and denoted with *MEC*. Similarly any benefits resulting from the production and consumption of the product and accruing to others than its consumers without compensation through the market, be called external benefit and denoted with *MEB*.

The model in the previous section is the (very unlikely) special case when  $MEC = MEB = 0$ , that is, when the production in question has no effect on anyone but its producer and its user. It is only in this case that we can justifiably say that the profit-maximizing behavior of the firm also leads to the welfare maximum of society.

To see why this is, let us suppose next that the manufacture of this particular product imposes costs on others in addition to the producer (so  $MEC > 0$ ), but brings benefits to nobody but the consumers (that is,  $MEB = 0$ ). This situation, also called negative externality, is seen in Figure 9.2.

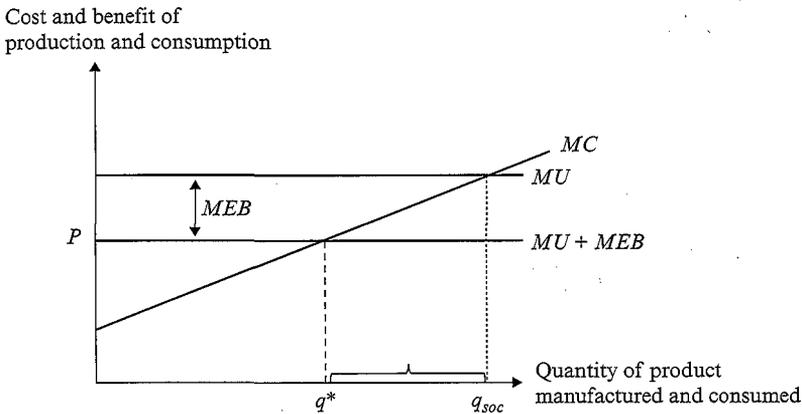
Since the external cost does not represent a cost to the producer, it will continue to produce  $q^*$ . For society, however, this product is now more costly than it appears to the producer: the last unit, for example, that the company is producing is valued lower by society in general than the resources used for its production and consumption. From a social point of view, the optimal quantity produced should be  $q_{soc}$ . The company is producing a few units (between  $q_{soc}$  and  $q^*$ ), which cost more to produce than they are worth to society as a whole. The problem is overproduction: the company is manufacturing too much from a social viewpoint.

An analogous explanation shows that the opposite case of a positive externality also leads to a socially inferior result. Let us now suppose instead that the manufacture of this particular product only costs the producer (so  $MEC = 0$ ), but brings benefits to other



Source: Own compilation based on Pindyck and Rubinfeld (2009).

Figure 9.2 Socially optimal quantity in the case of a negative externality



Source: Own compilation based on Pindyck and Rubinfeld (2009).

Figure 9.3 Socially optimal quantity in the case of a positive externality

members of society in addition to its consumers (that is,  $MEB > 0$ ). This situation is depicted in Figure 9.3.

Again since the external benefit does not represent additional revenue to the producer, it will continue to produce  $q^*$ . The last unit produced is more valuable to society than it appears to the producer. From a social point of view, the optimal quantity produced should be  $q_{soc}$ , the company is now not producing some units (between  $q^*$  and  $q_{soc}$ ) which would be more valuable to society as a whole to consume than it would cost to produce. The problem this time is underproduction: the company is producing too little from a social point of view.

In general, we can say that companies maximizing their profit will choose the quantity

where  $MU = MC$ , whereas for society a quantity where  $MU + MEB = MC + MEC$  would be optimal (Pigou 1932). In both these cases, the existence of externalities causes the company's profit-maximizing output to differ from society's welfare-maximizing output. The result in the first case is that something is produced that is more costly to society as a whole than it is worth, and in the second case something is not produced that would be more valuable to society as a whole than it would cost to produce. The invisible hand is not able to produce the best outcome, and people pursuing their own interest fail to simultaneously best promote that of society. We leave open for now the question of whether intending to promote the interest of society would in such cases promote that interest better than pursuing their own interest.

We can connect the above model of optimal choice about quantity to produce, in the presence of externalities, to two choices about innovation. Innovations can be a source of both external costs and external benefits. If we consider the decision on innovation as a binary variable (do we realize this innovation or not?), then the theory of externalities predicts that some innovations will be realized based on the innovator's decision that should not have been realized if society was to decide, or some innovations will be discarded based on the innovator's decision, although they should have been realized from society's point of view. If we rather consider innovation as a continuous variable (how much do we want to spend on research, how quickly do we want to proceed with the innovation, what features do we want to include), we arrive at a somewhat better analogy with the model of profit-maximizing production presented previously. In this case, that model will predict that a profit-maximizing innovator not considering the external effects of his or her innovation may choose to include some features that it should not from the point of view of society as a whole, or not to include some features that it should from a societal perspective. A responsible innovator would consider the external effects and would endeavor to behave in a manner closer to the socially<sup>6</sup> optimal.

## INTERNALIZATION OF EXTERNALITIES: A WAY OF MAKING INNOVATORS MORE RESPONSIBLE

The problem with externalities is that they result in socially inferior outcomes and owing to external costs and benefits not being connected to the parties involved in the underlying transaction. The party creating the externality (the source) may not even know about the external costs or benefits that its operation causes, or may legally ignore them since no monetary compensation is involved.

There are, however, methods to internalize the externalities and bring the actor's choice closer to the societally desirable. The main idea behind internalization is that the external (hidden) costs and benefits have to be made visible to the decision-makers. Economic theory refers to market-driven and governmentally intervened ways of internalization, as shown in Table 9.2.

The most direct way of internalization is when the government issues permissions for certain externality-generating activities or outright prohibits them. If someone is granted permission for a certain activity, they only have to be careful to conduct the activity according to the permission, but need no longer be concerned about how much externality is generated. If an activity is prohibited, then, again, there is no need to consider what

Table 9.2 Internalization of externalities

		Magnitude of externalities allowed . . .	
		. . . by the Government	. . . by the Market
Compensation for externality determined . . .	. . . by the Government	Prohibition/Permission ( <i>ethical permissions for clinical research</i> )	Release (product, service) charge ( <i>Pigouvian tax</i> )
	. . . by the Market	Trading rights ( <i>emission banking</i> )	Voluntary agreements/ Self-control

Source: Own compilation.

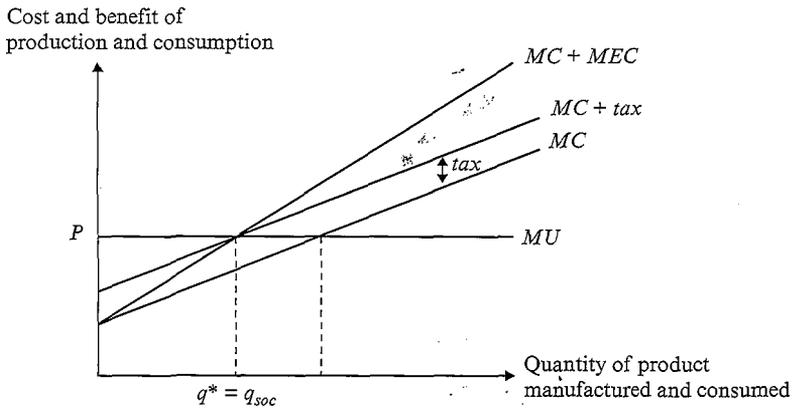
external effects would have been generated by the activity or how great they are. This is not a way of treating externalities that conforms to how free markets work, but it is extensively used. Typical examples of this type of government regulation include ethical permissions for clinical research intending to guarantee the rights and dignity of patients, which will be carefully considered and evaluated during the process. We hesitate to call a company responsible just because it does not do something that is prohibited, or because it behaves strictly according to some government prescriptions.

In other cases, the government is not so drastic but works with the market to internalize the externalities, that is, to make them relevant for the decision maker. In some instances, government sets a limit on the magnitude of the externalities, thus allowing the actors to arrive at an efficient way to reduce the magnitude of the externalities to that limit. In this case, the externality is priced by the market and in the short run this price tends to inversely depend on the magnitude of the externality that the government wants to allow. This type of internalization results in a new market for the rights of activities with externalities, as in the case of CO<sub>2</sub> emission trading.

In yet another case, there is a different type of division of labor between the government and the market: the government sets a fixed price for the external effect and the market is free to determine how much externality to generate at that particular price. This is what is referred to as the Pigouvian tax (Pigou 1932). Our previous model can demonstrate that if the government succeeds in setting a tax exactly equal to the marginal external cost generated by the activity, the producer, being the source of the externality and the payer of the Pigouvian tax, will adjust its decision to the new cost structure and will choose a level of production which also happens to be the socially optimal level, as seen in Figure 9.4.

Here again there will be an inverse relationship between the price set for the externality and its magnitude. The government will want to find that price for the externality (applied tax) at which the profit-maximizing actors would reduce the externality-generating activity to the socially optimal level. In the case of positive externalities, an analogous Pigouvian subsidy would be the solution. A public health product tax on foods with high levels of salt, fat or sugar, which was introduced in Hungary (referred to as the ‘chips tax’ in the public debate) represents an example of a government intervention along these lines.

In these last two cases, the internalization of the externalities works because property rights are clarified: the company now has a right to generate externalities if, and inasmuch



Source: Own compilation based on Pindyck and Rubinfeld (2009).

Figure 9.4 A Pigouvian tax resulting in the company choosing the socially optimal quantity

as, it pays the price. It is another matter as to whether the revenues generated can and will be used to provide some compensation for the external effects, that is, whether the compensation referred to in the Kaldor–Hicks efficiency criterion occurs. We are still reluctant to label a producer responsible if confronted with the externality in the form of an additional cost that they simply purchase a right to generate the externality.

The fourth means of internalizing the externalities works without any involvement from government. This is a voluntary agreement between stakeholders to reduce externality. The source of the externality notices that it is generating external effects (either because it is looking for the possible external effects it might generate or because it receives signals from outside parties affected by its activity), and without any obligation to do so, decides to consider these effects in the cost–benefit analysis. On many occasions while driving, we find ourselves in this type of situation. Right of way means somebody saves time and somebody loses time. If I have the right of way, being a courteous and tolerant driver, I might willingly give it up on some occasions when I notice others might save more time than I lose. In such cases the internalization occurs through empathy and self-control; there is no monetization and also no actual pricing. Though in this traffic example it was clear that I had the right of way, the need for voluntary agreements often comes from unclear property rights and the reciprocity of externalities: should I be tolerant with others or should they be tolerant with me? In a business situation, this translates to the question of whether the source should pay to be allowed to generate externalities or receive payment to refrain from externality-generating activities (Coase 1960).

In reality, the externalities will often not be internalized; that is, the effects will not be fed back to the source of the externality because this might be a less efficient way of mitigating the effects. When external costs are generated, it is generally an option for the affected person to avoid the situation. We can often see signs on sidewalks: ‘Overhead work! Pedestrian traffic on other side of road’. Starting to negotiate over the price for which each pedestrian would be willing to cross the road would be prohibitively costly

and ineffective. Instead, understanding that their safety is at risk, every pedestrian simply accepts the slight additional cost.

## OPERATIONALIZING RESPONSIBLE INNOVATION

Based on the linkages between responsible innovation and the neoclassical model of optimal choice in the presence of externalities presented in the previous chapter, we attempt to create an economic definition of innovation in line with RRI.

From an economic point of view, we define RRI as an innovation process with the results expected to be Kaldor–Hicks efficient, even after taking into account externalities which cannot be internalized through market mechanisms or government interventions.

More generally, research and innovation is responsible if it is expected to bring about more benefits than costs to all parties affected after voluntarily considering benefits and costs to parties that will in no way receive monetary compensation from, or pay any to, the innovator.

The external effects of any action, as we note previously, are manifold and far reaching; it would therefore be unrealistic to expect innovators to incorporate each and every one of them into the cost–benefit analysis. Therefore, the outcome will likely be suboptimal, but innovation, in our view, is responsible if it at least attempts to foresee, estimate and correct for unintended consequences. The condition is thus not on the actual outcome, but rather on the process. The institutional environment (for example, government regulations) can make it easier or more difficult for an innovator to act in accordance with the requirements of responsible innovation.

Before we provide a starting point to operationalize the definition above, we have to note some important circumstances:

1. In some cases of externalities, the methods of internalizing already exist and are being used, as in the case of environmental externalities. These include the Pigouvian tax and tradable pollution permits, and there is even a linkage between actual damage and its restoration formed by Payment for Ecosystem Services schemes.
2. In many cases, it is almost impossible to assess the effects of a decision because they only work out in the very long run, as in the case of health effects.
3. In addition to the macro-environment, the degree of the innovator's responsible behavior can also depend on what type of innovator we are discussing. Some innovators are more likely to enter non-tangible benefits and costs into their calculations than are others. We can expect the profit motive to be stronger in the case of companies doing research and less strong for research institutes. This can be attributed to the research institutes having a 'soft budget constraint' (Kornai 1986) compared to innovating companies.

If we say that the innovator is responsible if it voluntarily takes into account the external effects of the planned innovation before making a decision about innovating, then based on the theory of externalities, an innovator endeavoring to act accordingly will be faced with a number of questions:

1. How can the groups affected be identified?
2. How can the magnitude of the effect be measured?
3. How should the different effects be weighted and aggregated?
4. What scope of the effect can we expect the innovators to realistically assess and consider?
5. How can we establish feedback between the effects and the innovator?

It is still difficult to see how innovators could be made to start to think about the possible unintended societal consequences of their innovations. One reason is that societal consequences are difficult to define, grasp and measure. Innovators will most likely lack information about who might be affected and in what way.

If we connect the theory of internalization to the existing RRI literature, it can be stated that the socio-technical integration research (STIR)<sup>7</sup> is a possible element of internalization (fourth type in Table 9.2: voluntary agreements/self-control). It is a 'basic understanding of socio-technical integration, which we formulate as follows: any process by which technical experts account for the societal dimensions of their work as an integral part of this work' (Fisher and Maricle 2014, p. 3). Innovators in the natural sciences are paired up with a social scientist, who follows the progress of the research and constantly makes the innovator conscious of the embedding of the future innovation in society and urges the innovator to consider possible consequences of this embedding.<sup>8</sup> The STIR project is a good first step in providing innovators with valuable information. Becoming aware of possible future effects does not guarantee that the innovator will do anything differently, but being responsible implies that it will.

Another useful player in enhancing the degree of the innovator's responsible behavior could be the government. The invisible hand doctrine states that if the government only sets the rules of the game and allows the player to attempt to play the game to their advantage, given the rules, the outcome will be efficient. In the presence of externalities, the government might still play an important role in internalizing these externalities associated with innovation and incentivize companies to innovate more responsibly. The government could:

- decide to what degree companies are required to assess the possible unintended effects of their innovations (Only direct effects on consumers? All direct effects on consumers and innovations? Indirect effects also to the second, third, and so on degree?), thereby extending but also limiting their responsibility to society;
- create a feedback mechanism through which compensation for the effects under consideration can flow (additional revenues if the effects are positive and additional costs if the effects are negative). This provides an incentive for affected parties to become involved. In detecting potential external effects of the innovation, the innovators can use the wisdom of the crowd. All this can only be done if the process is highly transparent; or
- gather and disseminate information on companies' responsible innovation behavior.

## CONCLUSION

The primary aim of the chapter has been to take the first steps towards integrating economic tools and concepts into the multidisciplinary and interdisciplinary framework of responsible innovation. We introduced some economic principles to those scholars of responsible innovation who are not acquainted with theoretical economics and to show how these can be applied to the issue of responsible innovation. This chapter in no way intended to provide a complete economic analysis of RRI but, rather, to generate new thoughts in the literature and serve as a starting point for a future, more comprehensive economic interpretation and explanation.

We started out from the well-established definition of RRI from von Schomberg to bring our views more into line with the current state of RRI research. Introducing the concepts of utility and profit maximizing, we have shown that the question of responsible behavior among innovators surfaces when outside parties, possibly distant from the innovator itself, are affected at some point in time by the innovation process or by its outcome. Such unintended consequences and side-effects (positive or negative) that have been identified and acknowledged by RRI research are described in economics with the term 'externality'. In economics, the result of the presence of externalities is that even good-willed economic actors eventually behave in a way that is not societally desirable – the central problem of responsible innovation.

When innovators act according to the profit motive and consider costs and benefits relevant to themselves, and disregard the costs and benefits to others, they might: realize an innovation or include features that should not have been realized or included from the point of view of society as a whole; or not realize an innovation or not include some features into it that should have been realized or included from a societal perspective. Economic theory has offered some possible solutions to bring the profit-maximizing outcome more in line with what is societally desirable: a price on the external effects is set either by the market or by the government. Some external effects are already dealt with by either of these mechanisms and thus enter into innovators' calculations. Based on our understanding of externalities and their internalizations, we have formulated an externality-based definition of RRI. We have stated that the STIR project is a possible element of internalization, connecting the theory of internalization to the existing RRI literature.

It must be admitted that societal consequences are difficult to measure with any accuracy with hard measures. Still we believe that objectivity can be increased and that it is possible to provide guidance to innovators wishing to behave responsibly on how to do so.

We hope that our chapter will generate further discourse along these economic lines and form the starting point for further research. Relaxing the assumptions of the economic model, we might arrive at a more operational economic treatment of RRI. Future research may study how it might be possible to enter non-monetary side-effects into the cost-benefit analysis, how the indirect external effects can be measured and accounted for, what the role of government might be in internalizing and facilitating responsive behavior, whether it is possible to produce a set of RRI indicators that can be incorporated into grant applications or how it is possible to decide about the degree of responsible behavior with a lack of objective measures. It is also well worth asking whether RRI conformity depends on the macro-environment of the innovator and whether what we consider responsible innovation changes from country to country.

## NOTES

1. By the nature of the discipline of economics, the focus of its research is on consumers (who buy and consume things) and on companies (which sell and produce things). Throughout this chapter we use the general term 'companies' in a completely analogous manner for producers of innovations. It does not make much difference whether we are discussing a typical company that develops a new product or a privately or publicly funded research institute doing research (the latter very often realizes non-monetized revenues). We argue that the logic governing their behavior is the same in all cases.
2. The parties affected have an interest in the functioning of the company. Management literature often uses the term 'stakeholders' for such economic actors. We are not going to call them stakeholders because we want to emphasize that they generally cannot affect the company in question, are affected by it in a quite indirect way and are even difficult to identify.
3. The analogous question of more importance from the point of view of RRI would be how many resources to devote to innovation.
4. We may well suspect that the share of non-monetary costs and revenues is higher for research institutes than for innovating companies. If we consider a research center working on an innovation, part of its benefit might be the satisfaction from increasing the stock of knowledge of humankind or the professional acknowledgement of its peers. We argue that this share will be even higher when the research and innovation are responsible.
5. To do unintentional harm, we do not even have to misuse the product or service in question! Imagine everybody you know subscribes to the same mobile carrier service. This makes calling them cheaper to you (unintended advantages), but if they all use the same network it might become congested, with the unintended consequence of you not being able to make an important call someday.
6. The economic literature generally uses the term 'socially' while the RRI literature uses the term 'societally'. We use them interchangeably since they have the same meaning.
7. <https://cns.asu.edu/research/stir> (accessed 17 April 2019).
8. According to the STIR methodology, the social scientist involved in the research group is responsible for taking societal dimensions into consideration during the research. He or she will only be able to focus on certain highlighted parts of societal dimensions based on his or her expertise. There will remain elements of this dimension of the innovation that will not be noticed and internalized.

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