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Responsible research and innovation in contrasting innovation environments: Socio-Technical Integration Research in Hungary and the Netherlands

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ABSTRACT

Recently, the notion of responsible research and innovation (RRI) has been gaining momentum in policy and practice. The main claim of RRI is that social, ethical and environmental aspects should be taken into consideration in scientific research and innovation activities. Socio-Technical Integration Research (STIR) is one of the first tools emerging from RRI research that is designed to help research, development and innovation actors practically implement key aspects of RRI in their daily work. Since its inception in 2006, results from multiple international studies have demonstrated the possibility and utility of STIR, albeit in developed countries. In 2015, a STIR pilot study was conducted in the developing region of Szeged, Hungary. Its results are similar, but far from those achieved in developed countries. In this paper we explore what, if any, role the innovation environment plays in the outcomes of the implementation of RRI practices such as STIR. We analyze STIR results and effectiveness in the wider context of the national innovation environments of Hungary and the Netherlands. Our findings suggest that the innovation environment can affect the success and effectiveness of approaches such as STIR. As a policy recommendation, we therefore recommend that RRI approaches such as STIR be adapted to the innovation environment of the country concerned.

1. Introduction

While policy makers around the world deem technological development and innovation as essential for increasing or maintaining competitiveness, they also appear to be recognizing that such development may also entail socially undesirable outcomes, for instance in cases such as genetically modified food and jobless growth. Recently, the notion of responsible research and innovation (RRI) has been developed to offer new perspectives on addressing the societal outcomes of research, development and innovation (RDI). Rather than simply assessing the "implications" and "unintended consequences" of new and emerging RDI, RRI seeks to align research, technology development and innovation with public values in new ways, integrating broader societal, ethical and economic considerations into scientific and technological practices. Ultimately, this may help multiple actors cope with the uncertainty, complexity and ambiguity of new and emerging science-based innovations. To date, a diverse and robust set of research projects on RRI have been carried out to explore its definition, dimensions, framework conditions, and limitations e.g. Refs. [7,10,14,31,51,57,65,68]. Such research emphasizes both the need for and the difficulties of implementing RRI concepts practically into innovation systems, institutional processes and also the daily decision practices that take place on research and development work floors such as laboratories.

Since it builds on decades of scholarly thought and practices, numerous tools and approaches are available for integrating RRI concepts into RDI activities. These include Constructive Technology Assessment see e.g. Ref. [60], Real-Time Technology Assessment [30], Socio-Technical Integration Research (STIR), and Value Sensitive Design [69], among others.[1] Of these, the STIR approach has

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[1] See Ref. [24] for a comparative mapping of these and other approaches in relation to responsible innovation.

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produced a number of studies with documented results in a number of different national settings e.g. Refs. [22,25–27,37,45,61]. Since STIR results are typically reported using the analytical framework of midstream modulation [23], this facilitates comparison across studies. Accordingly, it can potentially serve as a useful indicator in order to compare the reception of RRI activities across different national contexts. STIR works by supporting and structuring interactions between experts from different disciplines (i.e. the humanities/social sciences, typically called 'embedded humanists', with natural scientists and engineers), who then collaboratively reflect on the context in which the innovative work is being carried out, thereby aiming to explicitly broaden research decisions beyond the mere technical considerations.

Looking through the relevant literature on both RRI and STIR, we observed that most research has concentrated on developed countries. For instance, of the thirteen countries in which STIR studies have so far been carried out, only Hungary (and possibly China) can be considered to be developing. And while there are increasing instances of studies pertaining to RRI more general being carried out in developing countries e.g. [14], RRI itself is arguably based on democratic and liberal values (such as freedom, participation and equality), and on "Western ethics" [76]. At the same time, numerous researches e.g. Refs. [4,8,40,63,72,76] showed that when integrating RRI in different – nonliberal – cultures, ethics, religion, values, culture, or innovation environment of the country concerned should be taken into account [76]. details this dilemma and emphasizes: since research and innovation have global nature owing to international cooperation, the understanding of 'responsibility' may differ causing conflicts. This emphasizes the importance of understanding – besides the notion of RRI itself – how RRI tools and activities can work in different national environments. For instance, the outcomes of a STIR program that was conducted in a less developed country, namely in Szeged, Hungary, point to the need to tailor STIR (or any other RRI-related approach) in light of the specific characteristics of that region [37]. Both studies conducted in Hungary suggest that their findings are related to the innovation environment in which they were conducted, and we suspect that Hungary's post-Soviet heritage may play a more general role in terms of both democratic values and innovation environment.

Accordingly, we seek to understand the practical implementation and uptake of RRI tools, using STIR as an example, in less developed regions and countries. This exploratory study therefore aims to investigate *whether the innovation environment plays any role in the outcomes of the implementation of RRI practices, in this case STIR.* In order to investigate this question, we explore which factors in different innovation environments might help explain differences in RRI/STIR implementation outcomes. In this exploratory analysis, we look for similarities and differences in practices of two countries: Hungary and the Netherlands. We set these countries in a wider context of their respective innovation environments. The reason for this choice is that both countries have documented STIR results; moreover, the Netherlands is similar to Hungary regarding as many indices as possible.

The factors that explain any differences in uptake of RRI/STIR in two different nations are admittedly numerous and complex. In order to make our exploration more manageable, and in order to frame it in terms that are most likely to be of central interest to policy makers and other innovation decision makers (innovation managers, investors, etc.), we choose to focus on a traditional comparative factor, the innovation environment. Such actors may be in a position to consider implementing RRI in the future, and in our experience are likely be skeptical of RRI concepts and practices. By exploring the above question, we also hope to inform understanding of how to tailor-make RRI approaches such as STIR in less developed environments. Such tailored approaches would, it is expected, facilitate greater uptake of RRI concepts, tools and practices throughout innovation processes not only at local and national but also at global levels.

The structure of the paper is as follows. The next part details the concept of responsible research and innovation and gives an overview of the methodological background of the STIR. This part is followed by the comparison of the Hungarian and Dutch STIR results containing a secondary and a primary comparison of their national and regional innovation environment. The paper ends with conclusion remarks and a future outlook.

2. The need for Socio-Technical Integration

Nowadays, technological development and innovation are essential for improving competitiveness of not only a company but also a territorial unit (regions, countries, integrations) [2,11,15,19,78]. In addition, faster innovation is needed to solve challenges like water supply, energy problems, health or environmental issues [74]. It was also assumed that industrial modernization and the commercialization of innovation would contribute to overcome an economic crisis like the one in the European Union [28]. Altogether, innovation is expected to contribute to the achievement of social and economic goals [77]. However, technological improvement and new innovations will undoubtedly raise important social and political issues that need to be addressed. E.g., technological developments may result in growing demand for machinery and less need for human workers in a company and it may contribute to the phenomenon of jobless growth, like in the United States [42]. Also, genetically modified organisms raised several questions and led to strong debate worldwide [1,28,36,46,58,70]. Recently, the use and effects of commercial drones cause debates because it may risk security, privacy, liability and ownership [54]. According to the Eurobarometer survey [20], although 77% of the respondents thought that science has positive impacts on society, around 60% of the respondents said that innovation has negative side-effects on human life and environment. The notion of RRI calls for taking such perceptions into account and may help to align science and innovation with social and public values.

2.1. The concept of RRI

Given the large investments that national governments and private firms make in research and innovation, and the possibilities for unintended consequences of these activities, calls arise for a more proactive approach. Specifically, more reflective and deliberative roles are envisioned for a broad set of actors so that the purposes, motivations and possible yet uncertain ramifications of innovation are taken into account early on and in a way that informs practical and ongoing decision-making [23,61]. The concept of responsible research and innovation is one attempt to respond to such calls.

The need for paying more attention to the linkages between science (technology) and society has been documented for years if not decades [30], and it has also appeared in sociology discourses [29]. In the case of human development, the impacts of technology are often analyzed through capability approach [5,49]. The term RRI also contributes to this attempt since it represents the increasingly important discussions about collaborations with the aim toward better innovations for a better society, and has gained momentum within academic discourse [50,64]. Regarding the concept of RRI, several scientific definitions were given in the past few years, which point out many aspects of the phenomenon (thus its multi- and interdisciplinarity) [7,10,51,56,65,68]. For instance, [55]; p. 675

gives a simple definition: "*Responsible innovation is a new and promising approach in addressing social problems through new technology and in dealing with diverging values in particular, thus addressing the dilemmas of sustainable development*". However, the scientific community bases its work most frequently on the definition of [59]; p. 9, and we also rely on this definition during our research work: "*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 (in order to allow a proper embedding of scientific and technological advances in our society)*". Altogether, research and innovation cannot be deemed responsible if it does not seek to anticipate potential ramifications, include numerous stakeholders at early stages, and respond to stakeholder and public values [28].[2]

In the European Union, there has been a growing need for institutionalizing socially and ethically responsible governance [9,28]. As a result, RRI has emerged on the formal agenda in 2011, and the Commission has defined the six keys "*for, with and by society*", namely public engagement, science education, governance, open access, ethics and gender equality [17]. Summarizing this and the conceptual background of RRI, elements of RRI can be divided into four groups [7]: *role of society* (society-orientedness, acceptance based on values, mutuality, and incorporation of stakeholders); *responsibility* (society-orientedness, ethics, desire and sustainability); *nature of the process* (interactivity, transparency, multidisciplinarity and consciousness); and *results* (society-orientedness, competitiveness and future-orientedness). All these elements are very close to the democratic and liberal values, but can be strange for non-democratic and non-liberal countries. While [76] details this dilemma in theory, there are some practical studies from developing countries (China, India, Indonesia, Viet Nam) pointing out that the cultural context of country concerned has to be taken account while incorporating RRI [4,8,40,63,72]. Ref. [12] details that the number of religious group in a country – as a proxy of cultural diversity – also influences the technological performance: the more diverse the country is in terms of religion, the higher the technological performance is. Thus, the context of culture needs to be taken into consideration while speaking about RRI. Although the successful approval of RRI depends on numerous factors, in this study we concentrate on only the role of innovation environment, since this is likely to be of central importance to stakeholders (such as policy makers, investors, and innovation managers, among others) who may be in a position to consider implementing RRI in the future but who would likely be skeptical of RRI concepts and practices.

A number of research projects related to RRI have explored the prospects of enhancing 'responsibility' in different research groups e.g. Refs. [24,26,44,71] in specific industries or organizations e.g. Refs. [13,34,52,53,55] in public sensitivity e.g. Refs. [3,32] and in education e.g. Refs. [33,41,48]. The European Union also works to foster the integration of RRI in the daily operations of research institutions [4,28]. Most of the methods are based on field-studies: researchers tried to integrate into the operation of research groups, and conducted interviews with members of the research groups at their research sites. For reasons stated above, we focus here on the Socio-Technical Integration Research (STIR) method.

2.2. Incorporation of RRI in natural science research with STIR

In order to outline how the innovation environment may influence the outcomes of the STIR method, firstly we introduce this representative RRI tool. We also highlight here that the same process went on in all labs with which we try to explore the impacts of innovation environment on the outcomes of the STIR. As a first step of STIR, the research groups in which the embedded humanist can work is chosen. Usually, in an invitation letter, the heads of research groups are asked for their or their delegates' participation. According to the experiences in developed countries, they are usually interested in the concept of STIR, and accept the invitation to join the project without much prior knowledge about the content and earlier experiences. In this phase, the principal investigator (PI) decides whether to participate in STIR or not. Once the PI accepts, then the embedded humanists solicit researchers from the group who are willing to actively participate in the STIR observation (as high interaction persons) and also researchers who remain so-called "no interaction" persons (or "controls"). The embedded humanists will be in active contact with the high interaction researchers. The controls are important for analysis of whether the observed changes in the way of thinking and doing in practice could be the result of interactions with the embedded humanist, or happen through the organization anyway. There is no requirement who can be a high interaction or a no interaction researcher; this depends only on the voluntary participation of the researchers.

During the implementation, usually one humanist is embedded in the daily operation of the research group of natural science. The interactions conducted with the participants consist of the following elements: a pre-study interview, a post-study interview, and in-between participant observation and discussion using a protocol for interaction (see below). During the pre- and post-study interviews, the embedded humanist raises the same questions to the high and no interaction persons, in order to catch traceable changes. The open interview questions aim to investigate whether and how interdisciplinary interactions may help enhance the integration of social and ethical considerations into research decisions. The pre-study interview is the beginning of the participant observation at the same time, during which the humanist visit the laboratory several times a week, usually for about 12 weeks, and monitors the activity of participants and recognizing their decision points throughout the continuous interactions. The humanists interact with the high interaction researchers while there is no contact with the no interaction researchers.

In order to catch the reactions of the researchers participating in STIR, a so-called STIR decision protocol is regularly used [22,23,26,27,61,62]. With the assistance of the protocol, embedded humanists can recognize the different decision components that lead to any given decision, through a collaborative process of co-description, where both the monitored and the communicated information is reflected upon. Therefore, these humanists ideally become involved in the decisions and strategies, even though they began as merely monitoring researchers [61]. The protocol can facilitate the collaborators to write down and even draw material together, in a transparent and collaborative manner. The main outcomes that are of major importance are: reflexive learning, value deliberations, and practical adjustments inspired by such reflections on broader socio-ethical and economic context [22,27].

The humanists document what kind of results are occurring, both quantitatively and qualitatively. Then they assemble some of the qualitative accounts in narrative form and/or tabular form, depending upon what seems interesting and insightful. Data on protocol exercises and observations are reported on in various ways, usually including narratives or 'stories' [23], figures [61] and/or tables [27]. As a result, the tailor-made integration built upon the specific features of the innovation environment will be able to integrate the RRI keys into the innovation process already at the

[2] RRI requires proactivity, see, e.g. [35], who details methods an actor can use to be proactive.

level of daily decisions, and to create a reflexive learning, which ensures that the researcher participating in the project will make decisions consciously and compatible with RRI.

The same STIR-structure took place in our two sample countries: in Hungary and in the Netherlands both an embedded humanist observed the work of a lab for 12 weeks, and analyzed the changes in the way of thinking. Both embedded humanists were trained in the same way ensuring that both humanists used the same STIR-techniques. All these enable to investigate and explore the factors which may cause differences in the outcomes of the STIR.

2.3. Outcomes in light of innovation landscapes

STIR has been used in many cases in countries which all belong to the 'innovation leader' or 'innovation follower' countries according to the European Innovation Scoreboard [18].[3] The labs themselves are industrial and university labs, mostly focusing on nanotechnology, synthetic, neuroscience and genetics. It has also been used in industrial biotechnology, microelectronics and materials labs. These studies tend to produce three types of outcomes: reflexive learning, value deliberations, and practical adjustments or deliberate modulations. In nearly all these cases, the laboratory participants came to see these developments as valuable for their own research e.g., [25,26,61].

Considering that STIR has only been tested in developed countries, numerous questions arise how effective the method works in underdeveloped ones. Since there is relatively low knowledge of RRI in Eastern European countries, a pilot research has been carried out by the question whether and how RRI could be institutionalized in Eastern European settings, where most of the countries belong to underdeveloped countries [37]. In that research, as a first step, the STIR researchers focused on whether and how the STIR method can be adapted to research and innovation decision-making in these countries. In order to answer these questions, STIR was tested in two natural science research groups at the University of Szeged (Hungary), and later among university students who plan to work as researchers in the near future [39]. The results show that STIR can be adapted for use in Eastern European countries, but certain steps would be needed to modify it in accordance with the special innovation features of these countries. The fact that STIR, when implemented in a country with moderate innovation performance, brought different results in comparison with the results of innovation leader countries, raised some questions of why these differences occurred and what the possible role was of their respective different innovation environments, as we described in Chapter 2 that RRI works in different cultures differently. In this study we attempt to find out why this may be the case and we explore the similarities and differences of Hungary and the Netherlands.

3. Exploring the outcomes of STIR methods implemented in the Netherlands and in Hungary

Since in our study we are focusing on the question whether the innovation environment has any role in the outcomes of the STIR method, firstly we have to investigate the wider innovation environment of the 'STIRed' labs. In spatial analyses we select a comparator area as follows [16]: one should find strong indices according to which the two selected areas are homogenous and others according to which the areas are heterogeneous. We looked for a comparator country to Hungary since we investigate the suspicions of the Hungarian STIR researchers. As a result, only countries can come up in which there have been STIR-projects and there are several indices according to which the country is homogenous with Hungary. In order to meet this requirement, we could select a country only from Europe but the size of the selected country should be similar to Hungary. Since Hungary is a post-Soviet country, the strong difference in the light of our research is that the comparator country should be a non-post-Soviet one.[4] Collecting the countries where there were STIR-researches, we found only some European countries: the Netherlands, Denmark, the United Kingdom, Spain, Belgium, Northern Ireland, France, and Switzerland.[5] Out of these countries the Netherlands and Belgium could meet the requirements of a comparator country, but only the Dutch study used the STIR protocol as extensively as the Hungarian one, so we chose the Netherlands as a comparator country.

3.1. Comparison of the Hungarian and the Dutch economic and innovation environment

In order to understand the similarities and differences of STIR projects implemented in the two selected countries, we have to investigate the wider innovation environment of the 'STIRed' labs. This helps us to connect the differences of the innovation environment and the different results of STIR studies. We used data from the Eurostat regional database [21] and the national statistics of the two selected countries and we took into consideration the most recent available data. In order to ensure comparability, we use per capita or proportion indices. Besides, we carried out a primary study, too, during which we conducted in depth interviews with professionals who know the innovation environment of both countries. Results of the primary research may give more detailed information on the differences of the two innovation environments.

3.1.1. Secondary analysis

The Hungarian STIR studies were conducted at the University of Szeged. They are located in Szeged in the NUTS2[6] region of South Great Plain. The Dutch STIR studies were implemented in NIZO food research B.V. in the Gelderland NUTS2 region and in Royal DSM N.V. located in the Zuid-Holland NUTS2 region.

In case we put the regions in wider context and before the regional analysis we compare the national data (Table 1), we can state the GDP per capita (in PPS) on the EU28 average shows significant differences in the two countries: in the Netherlands, the GDP per capita is 31 percentage point higher than the EU average while in Hungary it is 32 percentage point below the EU average. Similarly, the employment rate shows such differences: the value of this indicator is 11% higher in the Netherlands than in Hungary.

Regarding the innovation indices used often, significant differences can be experienced: the Netherlands is in a better position. In the Netherlands, 1.96% of the GDP is spent on research and development, while in Hungary only 1.4%. The extreme differences are shown by the GERD and BERD indices as well: both the per capita Total intramural R&D expenditure (Gross domestic expenditure on R&D – GERD) and the per capita Business enterprise R&D

[3] In innovation leaders, the innovation performance is above the EU average, while in innovation followers, the innovation performance is above or very close to the EU average [18].

[4] The influence of the Soviet era on innovation activity can be found in the study of [66] or [75].

[5] Other continents where STIR-studies were carried out include North America and Asia.

[6] NUTS (Nomenclature of territorial units for statistics) classification is used in the European Union to develop and harmonize regional statistics. There are three NUTS levels: NUTS1 refer to the country, NUTS2 refer to regions with a population of 800,000–3,000,000 people, while NUTS3 are smaller regions (e.g. county) with a population of 150,000–800,000 people.

Table 1
Main indicators of the innovation environment in the Netherlands and in Hungary.

Indicator (measure, year)	The Netherlands	Hungary
population (capita, 2015)	16,900,726	9,855,571
area (square kilometre, 2015)	41,542	93,011
GDP/capita in PPS (EU28 = 100%, 2014)	131	68
Activity rates (%, 2015)	79.6	68.6
R&D expenditure in the percentage of GDP (%, 2014)	1.96	1.40
Total intramural R&D expenditure − GERD (€; /inhabitant, 2014)	776.9	144.7
Business enterprise R&D expenditure − BERD (€; /inhabitant, 2014)	366.0	66.5
Total R&D personnel and researchers (head count/1000 inhabitant, 2013)	11.0	5.9
Patent applications to the EPO (per million inhabitants, IPC) (2012)	158.0	17.1
Corruption Perceptions Index (0 = highly corrupt, 100 = very clean)	87	51
People expressing high level of trust in each other (%, 2008)	80	47
Social-ethical issues in the legislation of innovation	yes	no

Source: own construction based on [21,47,67].

expenditure (BERD) are five times higher in the Netherlands than in Hungary. This value reflects to a very important fact with taking into consideration that the number of R&D personnel per 1000 inhabitants is 1.8 higher in the Netherlands than in Hungary: since the research personnel in the Netherlands is almost double in number than in Hungary while the Dutch can work on five times higher expenditure than the Hungarians, the underfinanced situation of the Hungarian R&D sector in comparison with the Netherlands can be noticed.

Looking at the output indicators measuring innovation activities besides the input indices detailed above, the Netherlands is again in a better position: the Dutch patent applications (in 2012) are double than the Hungarian.

Regarding corruption, on the list Corruption Perceptions Index,[7] Hungary is ranked 50 with a score of 51, while the Netherlands is ranked 5 with a score of 87, so the Netherlands is presumably less corrupt than Hungary, which belongs to the medium corrupt countries. Since trust among partners is critical to the performance of R&D [6], comparison of countries from the point of view of trust is also important. The OECD measures trust and social cohesion regularly: according to the trust indicator published in 2011 [47], 80% of the people expressing high level of trust in each other in the Netherlands, while in Hungary, only 47% of the people. The Hungarian value is not only lower than the value of the Netherlands, but it is also below the OECD average (59%).

Focusing on the most important legal and organizational background of the RDI activity in both countries, we also face important differences. The Hungarian Act on Research and Development, Technology and Innovation does not deal with any social or ethical issues. On the contrary, the Dutch Higher Education and Research Act (WHW) and the Research and Development Promotion Act (WBSO) has social and ethical relations. Furthermore, the *Netherlands Organization for Scientific Research* issued a large number of RRI calls, but the Hungarian *National Research, Development and Innovation Office* has not published anything about RRI yet.

Analyzing the indices of the Innovation pillar (12th pillar) of the Global Competitiveness Index calculated by the Word Economic Forum, the statements mentioned above can be more clear. The [73] competitiveness report calculating with hard and soft data puts the Netherlands on the fifth place, while Hungary is at the 51st place out of 140 countries. Regarding the innovation pillar, the difference is similar: the West European country is at the 8th place, while the Eastern European country stands at the 51st place. According to all sub-indices within this Innovation pillar, the Netherlands performs better than Hungary regarding both the rank and the score (Table 2).

The differences between the innovation performances are larger if we analyze data of the regions where the STIR projects were implemented in both countries (Table 3).[8] In both Dutch regions, more than 2% of the GDP is spent on R&D, while in the South Great Plain (HUN) it is only 1.21%. Furthermore, the Dutch results exceed the national average (1.96%), while the Hungarian region performs below the Hungarian average (1.4%). In the case of GERD, the Dutch results are ten times higher than the Hungarian value (while this difference is only five times at country level). The number of the R&D personnel in both Dutch regions is 2.11 times higher than the number of the Hungarian staff, however, this does not show significant difference in comparison with the national average. The regional differences exceeding the national averages in the case of number of R&D staff and R&D expenditure emphasize in a larger size the underfinancing of R&D activities in the Hungarian region: the research personnel which is approximately double in number in the Dutch regions than in the Hungarian one, can work on approximately nine times higher expenditure.

3.1.2. *Primary survey*

In order to better understand the differences of the innovation environment of the two selected countries, we carried out in-depth interviews with seven experts, who are familiar with the innovation system of the examined countries. Four of these experts lived in both countries for longer time,[9] while the other three experts investigated the innovation system of both countries, so all of them have relatively wide-spread practical experience on the similarities and differences of the innovation systems.[10] Regarding the interview protocol, we carried out 40–60 min long interviews with the same 15 open questions on the innovation system of both countries but the questions emphasized the comparison of the two systems.

All of the respondents find the innovation system of the Netherlands more developed than the Hungarian one. They mean

[7] It is published by Transparency International and ranks countries/territories based on how corrupt a country's public sector is perceived to be. It is a composite index, drawing on corruption-related data from expert and business surveys carried out by a variety of independent and reputable institutions. Scores range from 0 (highly corrupt) to 100 (very clean).

[8] Some indices (BERD, corruption, trust) are not available at regional level.

[9] Methodologically finding the experts was not a traditional selection rather a quest. The relevant population is relatively small: the number of persons who lived in both countries, on the one hand, and integrated into both innovation systems, on the other hand, is small.

[10] In this case, basic population is a bit larger but still small resulting in the possibility to cover with professional informal relations. Selection criteria were practical knowledge, daily interaction and international experience of the experts in order that they could evaluate the position of the system concerned in international context.

Table 2
WEF GCI's innovation pillar in the Netherlands and Hungary.

Criteria	NED rank	NED score	HUN rank	HUN score
Innovation pillar summary 1–7 scale (7 is the best)	8	5.4	51	3.4
Capacity for innovation 1–7 scale (7 is the best)	16	5.2	131	3.1
Quality of scientific research institutions 1–7 scale (7 is the best)	6	6.0	28	4.8
Company spending on R&D 1–7 scale (7 is the best)	18	4.8	97	2.9
University-industry collaboration in R&D 1–7 scale (7 is the best)	9	5.4	36	4.3
Government procurement of advanced technology products 1–7 scale (7 is the best)	21	3.9	104	2.9
Availability of scientists and engineers 1–7 scale (7 is the best)	22	4.8	51	4.2
PCT patent applications (applications/million pop.)	9	208.9	26	24.8

Source: own construction based on [73].

Table 3
Main indicators of the innovation environment in the STIR regions in the Netherlands and Hungary.

Indicator (measure, year)	Gelderland (NED)	Zuid-Holland (NED)	South Great Plain (HUN)
population (capita, 2015)	2,026,578	3,600,011	1,271,040
area (square kilometre, 2015)	5136	3418	18,335
GDP/capita in PPS (EU28 = 100%, 2014)	110	131	47
R&D expenditure in the percentage of GDP (%, 2014)	2.35	2.03	1.21
Total intramural R&D expenditure – GERD (€; /inhabitant, 2013)	758.7	782.6	85.3
Total R&D personnel and researchers (head count)/1000 inhabitant, 2013	11	11	5.2
Patent applications to the EPO (per million inhabitants, IPC, 2012)	96.666	121.915	15.714

Source: own construction based on [21].

that the Hungarian innovation system is in its early stage, in a learning process, where significant improvements of the last years are visible. However, in the older member states of the European Union, innovation facilities (such as science parks, technology transfer institutions, start-up ecosystem) are essential partners for implementing innovation strategies, while in the new member states such institutions were established only in the past 10–15 years, as were adequate strategic concepts. As a result, it is not surprising that the respondents also evaluated the general status of the Dutch RDI infrastructure significantly more developed that the Hungarian one.

As a consequence of the deeper roots of the Dutch innovation system, the institutions of the innovation system have more routine to deal with formal issues, so researchers use much more often the formal, official and documented ways to reach their goals than in Hungary, where the relatively new, often changing institutions are not accomplished enough. That's why the informal, personal relationships in administrative interactions which can significantly facilitate the office routine are very important in Hungary.

According to the in-depth interviews, the role of governmental financial support (grants and tenders, including EU financial sources) in stimulating innovation activities is much higher in Hungary than in the Netherlands. The interviewed experts also reflected that the main motivation for the innovation activity in Hungary is quite often the accessibility of public money instead of market demand regardless of the level of innovation history and innovation results of the company. All interviewed experts agreed that in the Netherlands market demands occur as encouraging factors of innovation much more frequently than in Hungary. Because of the underfinanced situation, Hungarian innovation actors are forced to look for external financial sources for their activities. Consequently, the dominance of EU-funds and „grant-driven innovation" as a phenomenon is clearly visible in Hungary.

The interviewed professionals experienced much more envy among innovators and scientists in Hungary than in the Netherlands. The Dutch share their knowledge on their scientific results and/or information on application possibilities more often than their Hungarian colleagues. The respondents find the level of reliance in the Netherlands significantly higher than in Hungary: Hungarian scientists trust in each other significantly lower than the Dutch scientists. Consequently, establishing innovation cooperations is much more difficult in Hungary than in the Netherlands.

The respondents form the opinion that the innovation mainly concentrates the capital and the main larger cities in Hungary. Contrary to this, technological innovation is far more decentralized in the Netherlands. The three Dutch technical universities are distributed over the country, not necessarily next to the largest cities, and industry innovation takes place distributed over the country.

Altogether we can say that the Netherlands is at a better position in this field, but in Hungary the problem itself is already identified and there are some – but mainly local – attempts to handle this challenge. Nevertheless, these Hungarian attempts are new and individual without any institutional framework. As a result, the Hungarian STIR-projects were not influenced by these factors: participants did not have preconceptions and were less aware of socio-ethical issues of their own research.

3.2. Comparison of the STIR projects

In the following we attempt to overview the process of STIR projects implemented in Hungary and in the Netherlands systematically. We provide an overview of both the method and the results, and identify the critical points (or milestones) which may be the consequences of the different innovation environment.

3.2.1. The methodological background of the STIR studies in both countries

In the selected countries altogether five STIR researches were conducted – 2 projects in the Netherlands and 3 in Hungary (Table 4). From methodological point of view, the framework of the STIR researches were similar in all project labs: the same method and STIR-techniques were applied for the same length of period (12 weeks), and all STIR projects involved almost the same number of researchers with similar qualifications.

The Dutch pilots were conducted in an industrial environment, while the Hungarian ones in academic environment. This is a crucial limitation of our study, however we stress that it is

Table 4
Main characteristics of the STIR studies in the Netherlands and Hungary.

Criteria	STIR HUN1	STIR HUN2	STIR HUN3	STIR NED1	STIR NED2
Host institution	University of Szeged	University of Szeged	University of Szeged	Royal DSM NV	NIZO food research BW
Region	South-Great Plain	South-Great Plain	South-Great Plain	Zuid-Holland	Gelderland
Topic	Oscillatory Neuronal Networks	Photo-electrochemistry	Bionics	Life Sciences	food and feed research and production
Applied method	STIR	STIR	STIR	STIR	STIR
Period	12 weeks (2015)	12 weeks (2015–2016)	12 weeks (2016)	12 weeks (2009–2010)	12 weeks (2011)
Number of involved researchers	4 (2 high interaction, 2 no interaction)	4 (2 high interaction, 2 no interaction)	7 (6 high interaction, 1 no interaction)	5 (high interaction, 0 no interaction)	10 project leaders (5 high, 5 low)
Status of involved researchers	2 PhD students	1 postdoc, 1 PhD student	university students	PhD trained researchers	PhD trained researchers
Number of trained embedded humanists	1	1	1	1	1
Scientific paper	[37]	[37]	[39]	[26]	[27]

Source: own construction

extremely difficult to recruit participants for STIR studies in Hungary from the academic environment, and impossible to find them from the industrial environment, in stark contrast to the situation in the Netherlands. Thus, the fact that we are able to offer comparable data for explorative analysis is a significant development for the scholarship around RRI, which is in a very early and preliminary stage, especially when it comes to developing nations and regions.

3.2.2. *Willingness of researchers to join STIR*

As stated above, the first step of STIR is to choose the research groups in which the embedded humanist can work and send an invitation letter. In the case of the Dutch studies, the same happened. In the end, three invitations were sent to three different organizations, who were all part of a large public-private research consortium that also the university was a member of. Two invitations were met positively by the organizations' RDI management, under the condition of voluntary involvement of the research groups. The other organization was not interested in, for unspecified reasons. On the contrary, in Hungary, there were large difficulties to find research groups which would participate in a STIR project. Following the practice of developed countries, an invitation letter was sent to 15 Hungarian research groups of natural sciences working at the University of Szeged, but the response rate was rather low: only 4 research groups responded, out of which only one researcher undertook one single interview, but not the full STIR participation. Out of the other 3 respondents two persons rejected, while another one partly accepted the invitation by delegating a college to a single interview. Altogether, in Hungary, no research group accepted full participation in a STIR-project voluntarily.

The unsuccessfulness of the invitation letters in Hungary was followed by personal invitation of researchers who the Hungarian STIR-leader had personal relations with, and this attempt closed with success. We expect that the following aspects mentioned before might have contributed to this phenomenon:

- lack of trust (as mentioned in Chapter 3.1.1)
- importance of informal channels (as mentioned in Chapter 3.1.2);
- Hungarian researchers and actors in the innovation process have limited information on RRI in general, and they do not understand why it would worth to learning more about it.

3.2.3. *The observation phase*

The 12-week observation of all five STIR-projects started with a pre-study interview. During these interviews, the Hungarian researchers admitted that they had no prior information and knowledge about responsible innovation. On the contrary, the Dutch researchers showed relatively more knowledge on this topic at the beginning of the studies, in any case in being aware that their research takes place within a larger societal context. That means that there was a slight difference in the starting point, which might also be explained because of the fact that the Dutch studies were carried out in industry rather than academia.

We also experienced that discussing basic social, ethical and economic issues of science and technology is more familiar to scientists in developed countries, also in the Netherlands, but it required much more time in Hungary: the Hungarian natural scientists could hardly understand why they as natural scientists should pay attention to social aspects, let alone see the value in that. The Hungarian embedded humanists had ample difficulties in having scientists address basic concerns (for example, possible negative side effects of researches; general relations of science and ethics). Altogether, the Hungarian humanists experienced that the Hungarian researchers concentrated only on their own core research and thought only in their own closed world. The social and ethical considerations, which are important for RRI, would only appear in their way of thinking after long talks. With other words: researchers show a limited understanding of their broader innovation system, and hardly perceive the social and ethical complexity of their research initially.

In other words: while the typical STIR studies involved protocol exercises on a regular basis, and only deviated from this due to the schedules of the research participants, the Hungarian pilots deviated for a unique reason: the previously agreed-upon time for conducting the protocol exercises was often used up due to the need to spend time fully discussing topics that were completely new to the researchers. It cannot be surprising since a typical Hungarian researcher must pay close attention to sustain the liquidity of the research (group) as a result of underfinanced environment (see Chapter 3.1.1).[11] Contrarily, researchers appear to be much more open minded in the Netherlands. Possibly they were familiar with the fact that they should pay attention to social aspects of their research, but had no means to structurally do so, or they could easily understand its necessity and possible value. In any case, it seems that Hungarian researchers were informed about RRI aspects for the first time by the STIR investigators, but the Dutch researchers got prior information from their innovation environment and education. They are also familiar with the complexity of

[11] However, there are some well-financed research groups in Hungary, but they are the most excellent research groups enjoying state support. In general, underfinancing is a feature.

their research in the whole innovation system.

The Hungarian STIR-leaders also noticed during the 12-week observation, that the participating researchers had to spend a lot of time on administrative issues of the host university.[12] Purchasing the necessary but not in advance planned and low value (2–3 EUR) tools for the research needs the same administration burden on researchers and time constraint as the purchase of modern, high-value technologies or tools. As a result, researchers take attempts to find loopholes and informal relations in order to overcome this situation and to avoid any delay in their work. Altogether, the Hungarian researchers themselves have to complete several administrative tasks in order to ensure their own working conditions.

On the contrary, the Dutch STIR-leaders did not seem to experience similar burdens: Dutch researchers have relatively lower administrative burden and other obligations due to bureaucracy in comparison with their Hungarian colleagues. R&D expenditures in the Netherlands are relatively high in comparison with other EU-countries, financing researches can be relatively better planned, there are relatively less additional administrative tasks of researchers in relation with the bureaucracy of the host university or research place. Perhaps this also may result in that they have relatively more time to consider their research in a wider context, along with its social and ethical consequences.

We must highlight that the presence of STIR investigators was disturbing for the Hungarian participating researchers, since they were unable to focus on their work requiring high level of attention through SITR-conversations, so this fact needs to be considered when it comes to methodological development. In the Netherlands this was much less observed. Interactions did take place on the laboratory floors and offices, but protocol discussions did not during intensive research activities.

In Hungary, scientists usually do not have work contact with other natural scientists and they do not see the point in involving other professionals (including social scientists like the embedded humanists) in their decisions and R&D activities. This possibly influences the results of STIR, since it took more time to talk with the embedded humanists. In the Netherlands, on the contrary, researchers seem to be more open-minded; cooperation is an ordinary part of their daily routine, so STIR-researchers could integrate into the lab work with less difficulty.

3.2.4. After the observation phase

Hungarian participants found beneficial to participate in the STIR-research, but as a reason they only could mention that several topics had been discussed that the researchers in this group had not been considering previously (e.g. the possible negative or undesirable use of his research results in the future, effective work organization, science communication).

In the Netherlands, in addition to such observations, the researchers claimed that they actually liked talking to the embedded humanists, considered STIR to actually be part of their work instead of a burden, and the studies even reported adaptive changes to ongoing practices that might in part be due to the fact that the researchers interacted with the embedded humanist.

So, as a similar observation, by the end of the 12th week, participant awareness at both countries had been enhanced, as evident in changing conceptions of RRI and socio-technical collaboration, and greater decision awareness. The difference is at the level of modulations observed in the two countries: while prior to the STIR activities some Hungarian participants tacitly integrated social considerations into their decisions (*de facto* modulation), by the end of the project they were more explicitly aware of these social aspects of their decisions and were better able to identify them as such (*reflexive* modulation). In contrast to this, all Dutch participants tacitly integrated social considerations into their decisions (*de facto* modulation), by the end of the project they reached a higher level of *deliberate* modulation [26].

The Hungarian examples of reflexive learning and changes in practice tend to be based on first-order reflexivity, which involves more efficiently accomplishing predetermined goals and values, rather than second-order reflexivity, which involves questioning predetermined goals and values (see Ref. [61] for the distinction between first and second order reflection). In the Netherlands observations on both levels were observed, but more first-order reflections in the earlier sessions, while gradually also second-order reflection started to occur towards the end of the studies.

4. Suggestions for a tailor-made STIR-method

STIR has spectacular results in the innovation environment of developed countries, and it helped – with slight modifications – the integration of natural and social sciences in more than 30 labs during the last decade. The application of the STIR method and subsequently the implementation of RRI in Hungary is influenced by special features. Maybe earlier studies did not observe this, because the research was done in a relatively similar innovation context, in developed countries. This research and the comparison of the Hungarian and Dutch results verified empirically that STIR works differently in different innovation environments resulting in more interventions of the embedded humanist. This raise the need to modify STIR if we liked to implement it in innovation environments differing from the developed countries'.

As an addition, perhaps one of the most important differences can be caught in the motivation according to which researchers of the two countries integrate the aspects of responsible innovation into their daily work. Earlier studies conducted in developed countries (including the Netherlands) showed the motivation of the researchers is to understand that these aspects are essential for the future. On the contrary, in Hungary, the actors only seem to consider direct costs and benefits, since owing to the surviving strategy and the former socialization process.

In case STIR is planned to be implemented in an innovation environment similar to that of Hungary, our work will be influenced by the fact that the places of research in general are underfinanced: from day to day researchers in these labs have to create the financial background of their research and this daily survival strategy may make them insensitive to the potential benefits of RRI, so they should be supported. To explain this, the Maslow's hierarchy of needs can help to understand individual motivation process. According to this theory, until a need at the bottom of the pyramid is satisfied, the satisfaction of a higher need cannot be expected [43]. In our case it means that until actors of innovation struggle for daily survival, the concept of the RRI cannot be realized completely as a higher level of need (Fig. 1). This have the practical message that effectiveness of implementing RRI can be increased in low-financed innovation environment if the implementation is

[12] Hungarian universities are extremely bureaucratized and securitized in comparison with most European universities in the sense of administration, daily operations and financial issues. The appointment of rectors and economic directors was become the authority of the ministry, after that, budget commissioners were ordered to the institutions. In 2014 chancellery system was introduced. According to the law of higher education, the chancellor does the actuation of the institution and is responsible for the 'economic, financial, controlling, accounting, labour, legal, administrational and IT activities of the institution of higher education, asset management of the institution, including the issues of technology, utilization of establishment, operation, logistics, service, procurement and public procurement, manages the operation in this field', moreover, in these fields practises the right of unity. The institutions of higher education have become double-led with the introduction of the chancellery system.

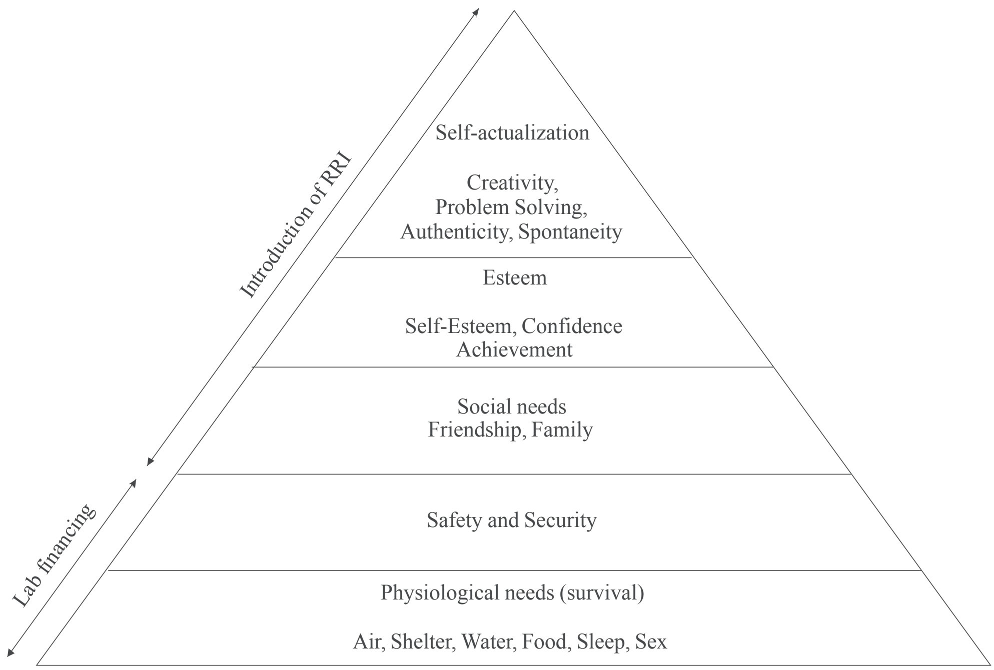

Fig. 1. Hierarchy of needs and possible level of RRI in developing countries.
Source: own construction based on [43].

converted to lower levels of the hierarchy of the needs. In other words: faster results can be achieved if goals we want to achieve are integrated into the costs and benefits of the actors, that is, in economic sense, externalities are internationalized [38]. This logic may be essential while preparing tailor-made STIR for underdeveloped regions.

To sum up, the methodology of STIR can be adapted to a different environment, though a number of specifics were identified during our research in Hungary that are presumably the consequences of the strategy of the socialist regime and the transition period. These have greatly influenced the innovation process and the possibility of the introduction of RRI. Thus the 'RRI readiness' of these countries is much lower than of the developed countries, so the introduction of RRI should start on the ground level in many less developed countries.

We assume that if STIR managed to be tailor-made and to implement in different innovation environments, it would raise STIR to higher level. However, it needs more research what kind of ways and aspects should be modified. In this research we only tried to prove that STIR works differently in different innovation environments.

5. Conclusions

The aim of this exploratory study was to investigate whether the innovation environment of a country plays any role in the outcomes of attempts to facilitate Responsible Research and Innovation (RRI), using the Socio-Technical Integration Research (STIR) method as an example. In order to investigate this, we analyzed both the outcomes of STIR studies conducted in Hungary and the Netherlands as well as the innovation environments of the research groups participating in these studies.

Our research suggests that the innovation environment influences not only the success but the effectiveness of STIR. Better understanding of the direct and indirect innovation environment and the possible motivations of the participating research lab is crucial. We also suggest that the relative level of research financing and as well as cultural background strongly influences the motivation of participants. One possible limitation of our research is that the Hungarian studies were conducted in an academic environment while the Dutch ones were conducted in an industrial context. While there may be differences in responsiveness to the STIR intervention between academic and industrial actors in the same country, we investigated and found that the attitudes and responses of the participants in Flipse's two Dutch industrial STIR studies (2013, 2014), from which the data for our study are draw, are similar to those reported by Schuubiers, who conducted a Dutch STIR academic STIR study (2011). Given this, and the immense difficulty we encountered in recruiting Hungarian scientists to participate in STIR studies in comparison to those of other countries, we expect that any such differences would be negligible for the purposes of our present study.

Although we have argued that implementing STIR in a less developed country or in a completely different culture compared to developed countries needs modifications. Although in this study we focused on the role of innovation environment in the outcomes of the STIR practices, regarding the methodological development of STIR, we should still consider several other things reflecting that its outcomes depend on numerous factors: length of the observation (12 or more weeks), cultural issues, educational differences, staff training, and discussion of ethics and values. These need further research and implementation of further STIR-projects.

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