



## An analysis of the emergence and evolution of the Responsible Research and Innovation (RRI)

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### Abstract

The concept of “Responsible Research and Innovation (RRI)” in this study examined from a systematic literature review perspective. Also we use scientometric approach to analyse RRI streams. A dataset of records Published between 1995 and 2021 is analyzed from Web of Science Database. The results were statistically classified based on bibliometric library of R software. Findings indicate that this concept has been evolving in recent years with the development of scientific concepts such as social innovation, corporate social responsibility and university social responsibility. The findings of this research can show a clear path of evolution in the field of innovation and responsible research. In this evolution, new concepts such as sustainability, ethics, public engagement, governance and innovation have been emerged.

**Keywords:** Responsible Research and Innovation (RRI), Systematic Literature Review (SLR), Scientometrics.

### Introduction

Responsive Innovation (RI) and Responsive Research and Innovation (RRI) have emerged in recent years as the most important issues in the relationship between innovation and research with society. (S. Stilgoe & Guston, 2017; Thapa, Iakovleva, & Foss, 2019). Rocco et al. (2011) listed four characteristics of responsible innovation as: (1) changes in existing arrangements, (2) consideration of equitable access, health, safety, and environmental concerns, (3) partnerships between government agencies, and other stakeholders and (4) long-term measures for anticipation and compliance (Roco, Harthorn, Guston, & Shapira, 2011).

Responsible research and innovation is a transparent and interactive process in which actors and innovators of society are held accountable based on acceptance (ethical), sustainability and social desirability, based on the process of innovation and marketable products. (In order to institutionalize scientific and technological advances in society) (René Von Schomberg, 2012; Rene Von Schomberg, 2013). While the origins of RRI date back to the early 1990s, the concept has received a great deal of attention since 2011 in the EU's policy and research communities (Owen, Macnaghten, & Stilgoe, 2012). The concept of RRI has been challenged by discourses on emerging technologies and research ethics in innovative fields. (Owen et al., 2012) It has been driven by EU's research and innovation policy over the past few years (Auer & Jarmai, 2018). RRI can be considered as a concept that has been developed to expand the scope of policy-making, to show the path of innovation and to determine the role of actors in society (Burget, Bardone, & Pedaste, 2017; Levidow & Neubauer, 2014). The concept of RRI is an attempt to promote a new method of governance in the direction of research and innovation. This method has been described as "a way to think more systematically about the general benefits of scientific and technological research." (Baldwin et al., 2013; Timmermans, Yaghmaei, Stahl, & Brem, 2017)

There are several definitions of the main factors of RRI discourse. For example, the broad definition offered by von Schomberg (Rene Von Schomberg, 2013) is closely related to the trends and values set out in EU policies (J. Stilgoe, Owen, & Macnaghten, 2013). Von Schomberg defined RRI as "a design strategy that drives innovation and achieves the desired goals of society" (Rene Von Schomberg, 2013). Most researchers in the definition of RRI have emphasized von Schomberg's definition (Bremer, Millar, Wright, & Kaiser, 2015; Forsberg et al., 2015). However, several other authors have provided their definition of RRI. Most of them who have given academic definitions of RRI have mentioned public engagement as a vital part of RRI. Other dimensions and aspects such as foresight, responsiveness, reflectivity, desirability, acceptability and innovation are sometimes mentioned (Burget et al., 2017). Stahl (2013) considers RRI as a trans-responsibility that defines the concept as follows: (Stahl, 2013)

*"RRI is a macro-level responsibility or trans-responsibility that aims to shape, maintain, develop, coordinate and align existing and new processes related to research and innovation, actors and responsibilities in order to ensure desirable and acceptable research results"*

RRI explicitly addresses issues of social development, social justice, and the extension of STI benefits. However, it is rarely articulated about this concepts in the subject literature (Ribeiro et al., 2018). Responsible Research and Innovation emphasize the importance of governance in innovation process (especially in the field of key stakeholders interaction and the need for inclusive and sustainable development) in the field of regional development (Thapa et al., 2019). Another important definition stems from another policy document issued in 2013 (p. 3) by the European Commission entitled "Options for strengthening responsible research and innovation". In recent years, another comprehensive definition has been provided as follows:

*RRI is a policy-driven discourse that has been grounded in the European Commission (EC) since 2011. At the macro level, its goal is to foster a comprehensive and sustainable research and innovation plan, with an emphasis on co-creation with society. ("Science with society and for society") (Owen & Pansera, 2019)*

Based on the EU's RRI Framework for Horizon 2020, RRI became a formal issue, and project funding began in the Science for Society program (now known as Science for and for Society). Therefore, in 2014, the mainstream RRI was introduced throughout the EU region through the "Rome Declaration on RRI" project (Thapa et al., 2019).

In this study, based on a systematic literature review (SLR) and scientometric methods, the evolution of the concept of RRI in the literature is investigated. Also, the selected articles identified by the SLR method from different textual dimensions regarding journals, collaboration network, co-citation network, collaboration worldmap, historical direct citation network, and emergence of new concepts are analyzed.

### **Literature Review**

In May 2011, the EU demonstrated its commitment to RRI through a number of related measures (including funding a program of research support and coordination activities under the Fourth Plan (FP7) in the Horizon 2020 project) and Formed a committee to promote RRI-related programs. The executive regulations of the Horizon2020 program are primarily based on cooperation between science and society and strengthening public trust in science (Burget et al., 2017).

In 2012, the EU Commissioner for Research, Innovation and Science Maire Geoghegan-Quinn formally announced her support for EU RRI policies. The EU's recent "Open Global Interaction" agenda in partnership with non-European countries is also on the RRI discourse. (Owen & Pansera, 2019) However, beyond Europe, there is a relative awareness

of the concept of RRI in emerging global economies (Brazil, India and China) as well as in some advanced economies (Japan, Australia). (Brom, Chaturvedi, Ladikas, & Zhang, 2015) If the concept of RRI is to be considered as a concept recognized in other countries and other research initiatives and fields, it must be able to take significant relevant action. Participating and interacting with global science and technology actors and their distinct needs can work for nations where the RRI discourse is underdeveloped and not considered a priority. To be able to make innovation and research transparent and responsible (Macnaghten et al., 2014).

The European Commission described six distinct dimensions termed as follows: engagement, gender equality, science education, ethics, open access and governance ("Regulation (EU) No 1291/2013," 2013). Of course, the concept of ethics and some other related issues in science, technology, research and innovation is not a new topic in general, but the concept of RRI has recently been introduced to include responsibility in research and innovation policies and methods. (Flick, 2016; J. Stilgoe et al., 2013; Rene Von Schomberg, 2011)

Stahl (2013) focused his research on the practical implementation of the dimensions that arise for actors, norms, and activities. Various authors have referred to previous dimensions that were not originally associated with RRI (Stahl, 2013). Stilgoe et al. (2013) mentioned four dimensions that were raised during the general debates: anticipation, inclusion, reflexivity, and responsiveness. This framework for RRI focuses on four integrated dimensions (J. Stilgoe et al., 2013) This classification was adapted and adopted by the UK Engineering and Physical Sciences Research Council to form the AREA (anticipation, reflection, engagement and action) framework (Owen, 2014). Stilgoe et al. proposed a broader definition of RRI 'taking care of the future through collective stewardship of science and innovation in the present' in 2013. (Stilgoe et al., 2013, p. 1517).

### **The Proposed Study**

In this paper, a comprehensive scientometric study in the field of responsible research and responsible innovation has been conducted. In the first step, ISI papers in related fields were extracted from the WOS database. In the next step, after initial screening and identification of related articles in terms of title, abstract and content, the final articles were analyzed based on an analytical-process package called "Bibliometrix" in R software. This analytical-process package is a tool for quantitative research in the field of scientometrics that is used for statistical analysis of articles extracted from citation databases. These statistical analyzes that have been used in this study have been in the fields of analysis of scientific collaborations of researchers, co-citation and synergies between scientific activities. These statistical analyzes have been performed on scientific collaborations of researchers, co-citations and synergies between scientific activities (Aria & Cuccurullo, 2017).

In the first search on the Web of Science citation database, the keywords "Responsible Research" and "Responsible Innovation" were searched. 861 articles were identified in English between 1990 and 2021. Then, in the first screening step, 648 articles were selected based on the subject area and journals. Also, in the next screening, from the perspective of reviewing the title and abstract, 572 articles were finally selected for scientometric analysis in the field of responsible research and responsible innovation.

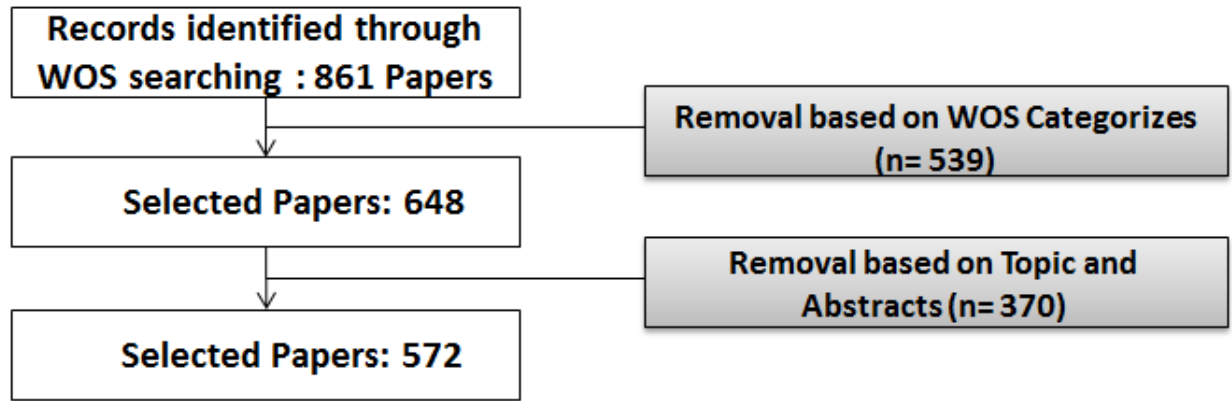


Fig1: Flow diagram of article selection

Scientometrics is a tool for quantitative analysis and statistical evaluation of documents such as journal papers and the number of citations. Today, these analytical methods are used to assess the growth rate of concepts, leading authors, and the mind and concept maps of research. These tools can also be used to identify the evolution of scientific societies and evaluate research performance in various fields. The existence of effective statistical algorithms, access to quality numerical routines as well as integrated information imaging tools are the most important qualitative features that make researchers prefer R programming language to other languages for scientific computing (Aria & Cuccurullo, 2017).

#### Descriptive statistics of selected articles

Based on the results of scientific search and screenings, the descriptive statistical information of the selected papers is presented in table 1:

Table 1: the descriptive statistical information of the selected papers

Description	
Articles	572
Period	1990:2021
Average citations per documents	11.22
Authors	2037
Author Appearances	2411
Authors of single authored documents	121
Authors of multi authored documents	1916
Documents per Author	0.284
Authors per Document	3.52
Co-Authors per Documents	4.17
Collaboration Index	4.3

As shown in Table 1, based on scientometric analysis, 572 selected articles of this research were analyzed. Indicators of mean citation and co-authorship are also expressed. Figure 1 shows the annual production trend of articles over a period of time. As can be seen in the figure, the upward trend in science production in the field of responsible innovation and research is very evident.

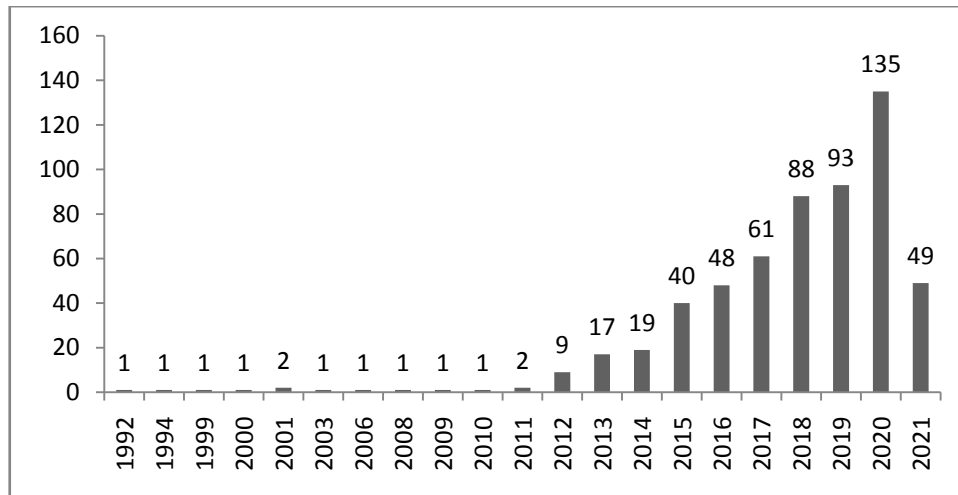


Fig. 1. The WOS selected publications on the analysis of responsible research and responsible innovation from 1990 to 2021

In Table 2, the 10 most referenced articles are ranked. Also, their average annual citation for each article is stated.

Table2: Descriptive analysis: Top 10–Most cited papers

Paper	Total Citations	TC per Year
STILGOE J, 2013, RES POLICY	718	79.7778
OWEN R, 2012, SCI PUBL POLICY	492	49.2
YANG GZ, 2018, SCI ROBOT	177	44.25
SOM C, 2010, TOXICOLOGY	139	11.5833
DONDORP W, 2015, EUR J HUM GENET	131	18.7143
FLEMING AJ, 2007, LARYNGOSCOPE	107	7.1333
GERGEN KJ, 2015, AM PSYCHOL	98	14
HALME M, 2014, BUS STRATEG ENVIRON	93	11.625
BOGOUSLAVSKY J, 2003, STROKE	89	4.6842
PIDGEON N, 2013, NAT CLIM CHANGE	76	8.4444

Out of 572 selected articles, 94 are related to the journal entitled: "JOURNAL OF RESPONSIBLE INNOVATION". The 10 journals with the most selected articles in the field of social innovation and social responsibility are listed in Table 3 along with the number of articles included.

Table3: The 10 journals with the most selected articles in the field of social innovation and social responsibility

Sources	Articles
JOURNAL OF RESPONSIBLE INNOVATION	94
SCIENCE AND ENGINEERING ETHICS	38
SUSTAINABILITY	33
NANOETHICS	29
SCIENCE AND PUBLIC POLICY	12
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	10
RESEARCH POLICY	9
ETHICS AND INFORMATION TECHNOLOGY	8
JOURNAL OF AGRICULTURAL & ENVIRONMENTAL ETHICS	8
SCIENCE TECHNOLOGY AND SOCIETY	8

The results of reviewing the references of 572 selected articles showed that 724 referenced articles were from the journal entitled: "JOURNAL OF RESPONSIBLE INNOVATION". There are also 619 articles cited in the journal entitled: "Research Policy". Table 4 shows the journals with the most citations.

Table4: The summary of the most cited journals

Sources	Articles
J RESPONSIBLE INNOV	724
RESPONSIBLE INNOVATI	640
RES POLICY	619
SCI ENG ETHICS	450
SCI PUBL POLICY	409
NATURE	313
SCI TECHNOL HUM VAL	312
SUSTAINABILITY-BASEL	264
PUBLIC UNDERST SCI	262
TECHNOL FORECAST SOC	256

There are various software tools that help researchers analyze scientometrics, but some of them are much more widely used. Among them can be software tools are Biblioshiny (Runs in R, 2019)(Moral Muñoz, Herrera Viedma, Santisteban Espejo, & Cobo, 2020), BiblioMaps (Runs in Python,2018)(Moral Muñoz et al., 2020), CitNetExplorer(Van Eck & Waltman, 2014), VOSviewer(Van Eck & Waltman, 2010), SciMAT(Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2012), BibExcel (Persson, Danell, & Schneider, 2009), Science of Science (Sci2) Tool (Team, 2009) and CiteSpace (Chen, 2006).

### Findings

Based on the Co-Citation Network, researchers' citation network can be observed in the field of scientific production of responsible innovation and responsible research. Scientific articles of researchers such as Stilgoe, 2013, Owen, 2012 and Von schomberg, 2013 have the highest density in the rate of co-citation in the network. These articles promote strong networks around themselves by presenting the basis of scientific discussions on innovation and responsible research.

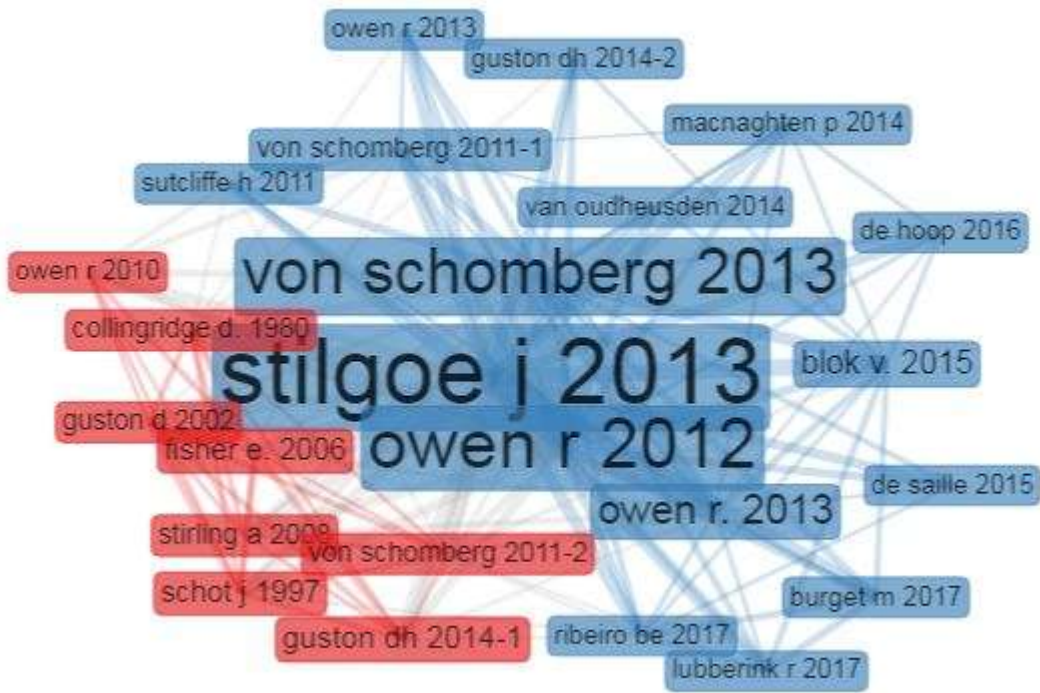


Fig2: Co-Citation Network

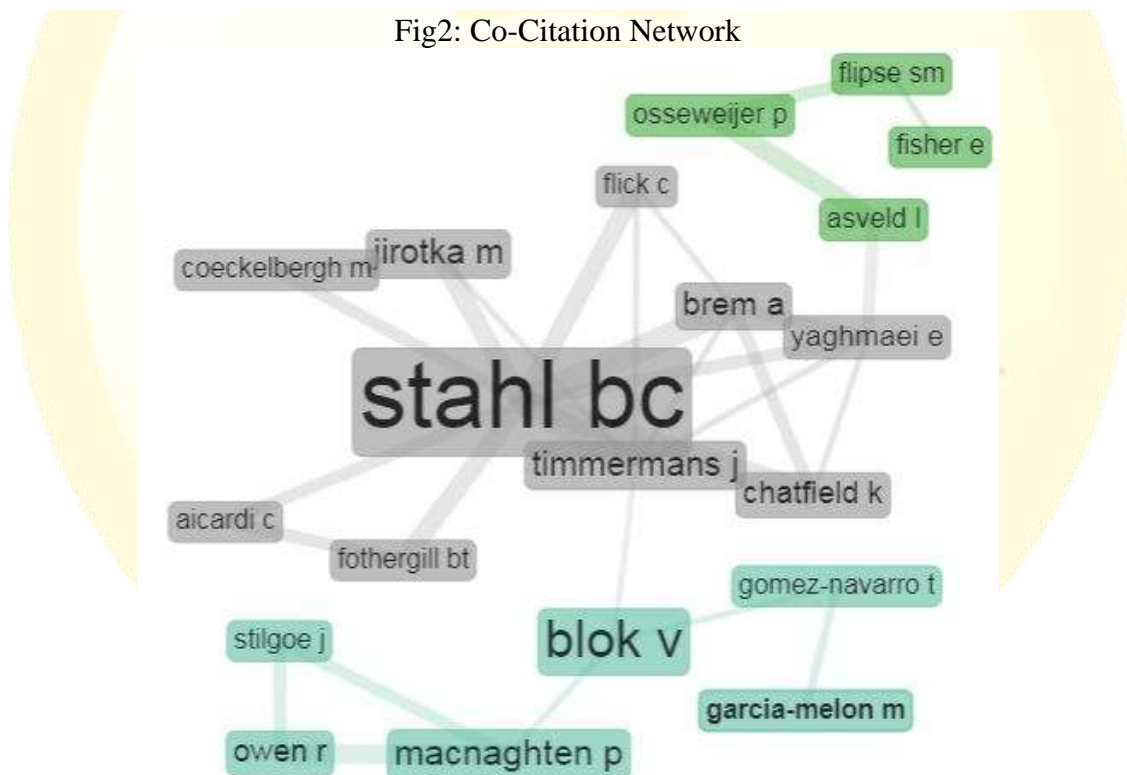


Fig3: Researcher's Collaboration Network

Figure 3 shows the network of collaboration between the authors of the articles by analyzing 572 selected articles. As can be seen in the figure, Stahl bc was able to create the largest network of scientific production cooperation in this scientific field. In this regard, Blok v and Yaghmaei, who are also known as Stahl co-authors in articles, have been able to feed other scientific networks as scientific mediators. Based on Figure 4, in the last decade, Stahl bc has been able to present the most cited scientific papers in the field of responsible innovation and responsible research. Next to him are Blok v and Lehoux P.

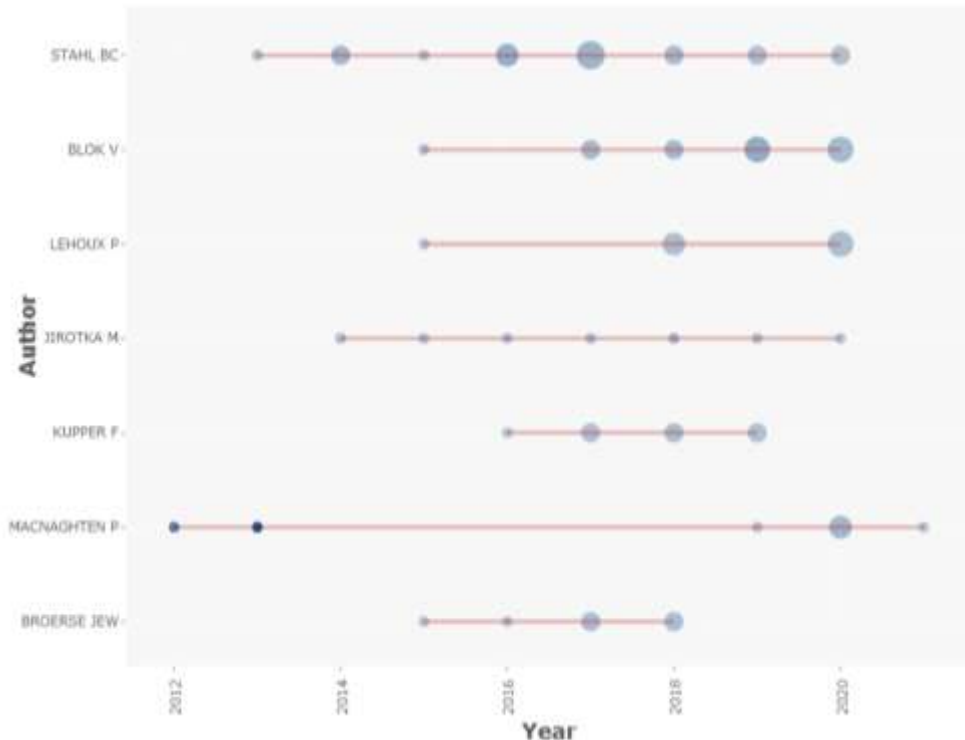


Fig4: Top-Authors Production over the Time

Figure 5 shows the countries that have the most citations in scientific products in the field of responsible innovation and responsible research. As we can see from the results of the figure, the beginning and evolution of this concept started with considerable intensity from the European Union and strong cooperation has been formed between European researchers and other researchers in the United States, Australia and Canada. It is expected that in the near future, this concept will be given more attention in developing countries, especially Asian countries.

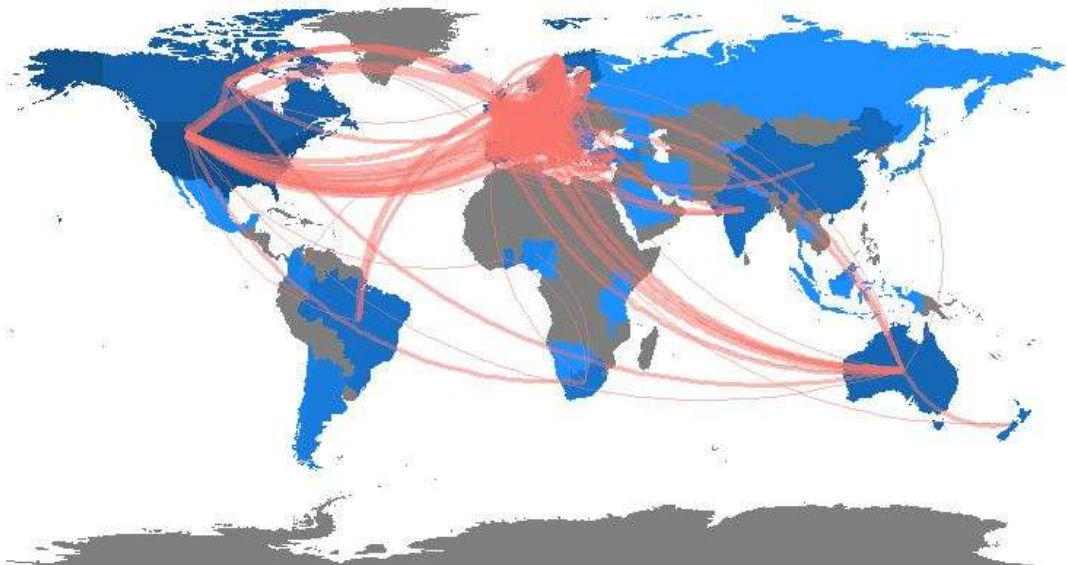


Fig5: Collaboration Worldmap

Figure6 shows the path of science development by various researchers in the field of innovation research and responsible research based on the Historical Direct Citation Network. Based on what we see in the figure, Owen, 2010 and Robinson, 2009 are known as the basis of the historical chain of production of the relevant sciences. A historiographic



map is a graph provided by E. Garfield to represent a chronological network map when it relates to the most direct citations from a bibliographic collection.

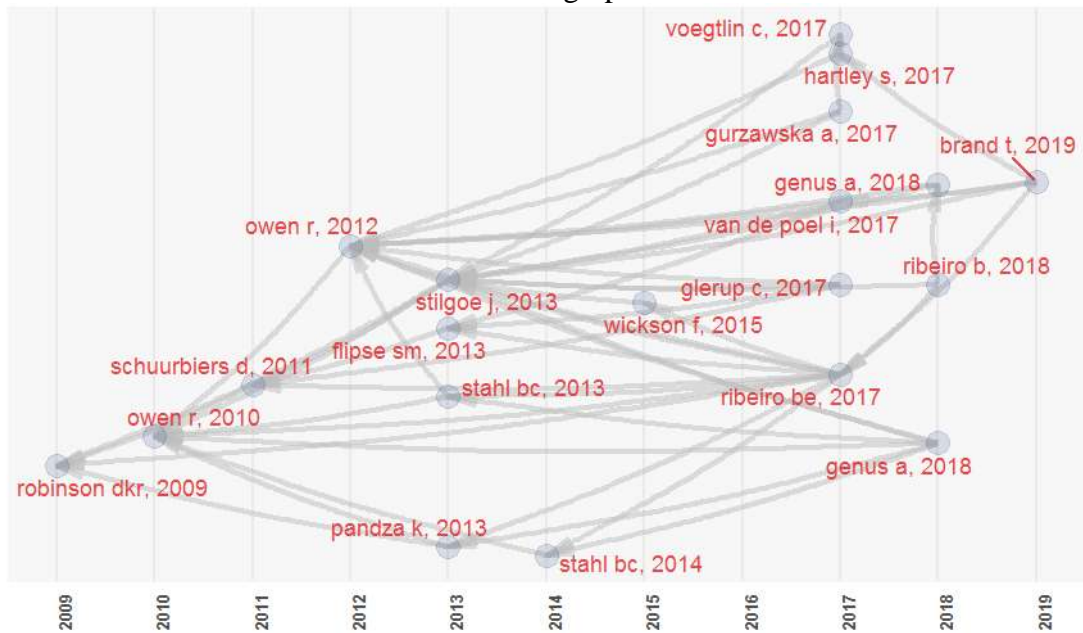


Fig6: Historical Direct Citation Network

Based on the keyword analysis of 572 selected articles, the results in terms of words occurrence are shown in Table5. The new concept of "Responsible research and innovation" ranks first with 160 repetitions in articles. The keyword "Responsible innovation" has since been repeated 120 times. The keywords "Ethics" and "Governance" are also in the next categories.

Table5: Words Occurrence in Selected Papers

Words	Occurrences
Responsible Research and Innovation	160
Responsible Innovation	120
Ethics	44
Governance	37
Nanotechnology	26
RRI	26
Innovation	25
Synthetic Biology	24
Sustainability	23
Public Engagement	22

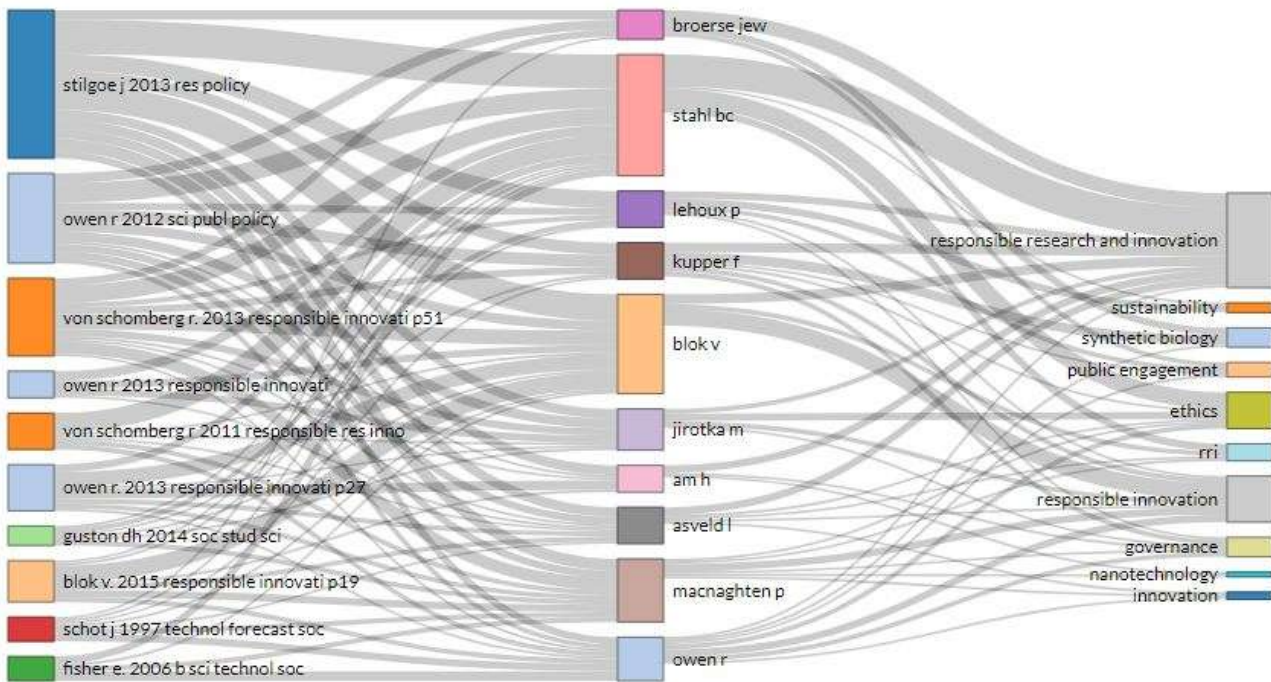


Fig7: Analysis of emerging concepts in selected papers with Biblioshiny

Figure7, obtained with the help of R software tools, shows well that in the scientific literature in the field of responsible innovation and responsible research, new concepts such as sustainability, ethics, public engagement, governance and innovation have been able to play more prominent roles. These issues can be very significant for relevant stakeholders at the relevant academic and executive levels.

### Conclusion

Responsible Research and Innovation (RRI) refers to a holistic approach that provides the following to the various stakeholders in the early stages of research and innovation processes:

- A) First, it allows stakeholders to identify relevant knowledge about the consequences of their actions and to consider it in later stages of the investigation.
- B) Second, it helps stakeholders to effectively evaluate results and options in terms of social needs and ethical values.
- C) and finally uses the above considerations as functional requirements for the design and development of new research, products and services (Burget et al., 2017).

in the first step of this study, based on the SLR method, identified scientific articles in the field of responsible innovation and responsible research from the WOS database. Then, with screenings and selection of 572 articles, the second step was performed based on the steps of analysis using scientometric tools. With the introduction of the above concepts from the European Union in recent years, today, the field of responsible research and innovation has expanded rapidly in developing Asian countries as a growing necessity. This issue should be considered at the academic level as well as the relevant executive levels in different countries.

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