Technology Dynamics (MOT113a)

READER (2023-2024)

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Table of Contents

IMPORTANT!

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0. Responsible Innovation and the 4th Industrial Revolution

Dr. Claudia Werker

Ever since the first *industrial revolution* innovation has been considered as the major driving force of socio-economic well-being and economic growth. In the meantime we have had two more industrial revolutions and stand at the beginning of the fourth one (cf. this and the following e.g. Brettel et al., 2014, p. 37). The first industrial revolution at the end of the 18th century was trigged by the water- and steam-powered mechanical manufacturing. During the second industrial revolution at the beginning of the 20th century was driven by mass manufacturing. The third industrial revolution in the 1970s emerged from the introduction of programmable logiccontrollers (PLC) for automation purposes in manufacturing. The fourth upcoming industrial revolution has been set off by the internet allowing human-machine interaction throughout large networks.

Responsible innovation is core to better employing and exploiting the potential of science, technology and innovation by considering and incorporating values, i.e. "things worth striving for" (Taebi et al., 2014, p. 119), societal needs as well as economic opportunities. (Taebi et al., 2014). "[I]n an ideal situation, responsible innovation can best be conceptualized as an endorsement of the relevant values during the innovation process" (B. Taebi et al., 2014, p. 118). In practical terms innovative agents can only achieve this by by considering the contextual factors of their own organization, e.g. a company, and its environmental factors (cf. this and the following van de Poel et al., 2017). By developing strategies in the form of shared values, joint activities, monitoring, experimentation, trust-building, openness to novelties and legitimization of innovative agents. These agents can come from various backgrounds, such as industry, university, civic society and government can contribute to processes of responsible innovation.

The purpose of this course is to show how innovative agents (see Sections 2., 3., 4.) can contribute to innovation (see Section 1.) and more broadly responsible innovation (see Section 6.) in order to use the developments of the fourth industrial revolution (see Section 0.) and digitization (see Section 5.) to serve all (see Sections 7.).

Video: https://www.youtube.com/watch?v=qhLvhYFLoWE

Readings for Chapter 0:

Brettel, M., Friederichsen, N., Keller, M., & Rosenberg, M. (2014). How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective, p. 37

Taebi, B., Correljé, A., Cuppen, E., Dignum, M., & Pesch, U. (2014). Responsible innovation as an endorsement of public values: the need for interdisciplinary research. Journal of Responsible Innovation, 1(1), 118-124, https://www.tandfonline.com/doi/full/10.1080/23299460.2014.882072

van de Poel, I., Asveld, L., Flipse, S., Klaassen, P., Scholten, V., & Yaghmaei, E. (2017). Company Strategies for Responsible Research and Innovation (RRI): A Conceptual Model. Sustainability, 9(11), https://www.mdpi.com/2071-1050/9/11/2045/htm

1. Innovation: Concepts and Measurement

Dr. Claudia Werker

1.1 Concepts of Innovation

Generally speaking *innovation* is a novel idea that has been developed and transformed into a product, process or service and/or has been commercialized (Popadiuk and Choo, 2006). In the following, the broad view of *technology dynamics*, i.e. studying science, technology and innovation from an evolutionary point of view, we do not only include economic but also social and ethical aspects to explain the emergence and evolution of processes leading to innovation, technological change and growth (European Commission, 2013). In this context we use the term responsible innovation (see Chapter 6.) as well as responsible research and systems (see Chapter 7).

There are many ways of distinguishing different kinds of innovation. In the following we will focus on two of them. First, we distinguish radical innovations from incremental ones as this distinction points at the influence an innovation has on the innovation system (find the definition in Chapter 2.2). *Radical innovations* fundamentally change existing practice, basically upending the whole innovation system (e.g. Popadiuk and Choo, 2006, and the literature cited there). In contrast, *incremental innovations* do not disrupt the way innovative actors operate and relate to each other (e.g. Popadiuk and Choo, 2006, and the literature cited there). They also do not require substantial changes of the formal and informal institutions, e.g. laws and codes of conducts of the innovation system.

The second way of distinguishing innovation points at different aspects of economic processes that are influenced by innovation, i.e. process, product, service, organizational and market innovation. All these kinds of innovation could be radical or incremental in nature. When an organization introduces new elements into its production process, e.g. new materials or additional information as well as task specifications we call this a *process innovation* (e.g. Popadiuk and Choo, 2006, and the literature cited there). In contrast, *product innovation* points at novel elements in a product, *service innovation* at those in a service (e.g. Popadiuk and Choo, 2006, and the literature cited there). Organization and market innovation emerge from new knowledge. *Organization innovation* refers to new ways in which an organization deals with knowledge, i.e. exploitation (the use of existing knowledge) versus exploration of knowledge (the creation of new knowledge) (e.g. Popadiuk and Choo, 2006, and the literature cited there). *Market innovation* points at ways of novel knowledge emerging from or being embodied in supply and distribution channels as well as customer expectations and preferences (e.g. Popadiuk and Choo, 2006, and the literature cited there).

Video:

https://www.youtube.com/watch?v=ZCUcrv-7yoE&feature=youtu.be

Readings for Chapter 1.1:

European_Commission. (2013). *Options for Strengthening Responsible Research and Innovation*. Luxembourg: European Commission Retrieved from ISBN 978-92-79-28233-1. http://dx.doi.org/10.2777/46253

Popadiuk, S. and C.W. Choo (2006): Innovation and knowledge creation: How are these concepts related?, in: International Journal of Information Management, 26, 302-312. http://dx.doi.org/10.1016/j.ijinfomgt.2006.03.011

1.2 Measurement of Innovation

To describe and measure innovation we use various indicators that come with advantages and disadvantages.

1.2.1 Innovation Indicators

There are many innovation indicators (for details see Freeman and Soete, 2009; Nelson 2009) and here we present them according to their stage in the innovation process. Thus, we distinguish innovation input, throughput and output measures:

- Measures of innovation input
    - R&D investment
    - R&D personnel
- Measures of innovation throughput
    - patent citations
- Measures of innovation output
    - patent applications
    - patents
    - number of process and product innovations
    - literature-based innovation output indicators, e.g. publications
    - sales of innovative products

Innovation indicators come with advantages and disadvantages (see for the following Freeman and Soete, 2009; Nelson 2009). To give an example, patents, patent applications and citations are often used, because they are publicly available in long time series, classified according to technical fields and relatively consistent over time. On the other hand side, patents have disadvantages as well. Here, we point to the most prominent ones: The propensity to patent differs by firm size, sector and country. Patents do not account for all those innovations that are not patented, e.g. those that firms keep secret to protect their competitive advantage. Moreover, firms often patent strategically, i.e. they do not only patent what they actually intend to use but also what they try to hinder others from using. Therefore, the latter patents are not really used and might have little or no economic value.

While innovation indicators can provide useful information for management and policy they can also be abused strategically. First of all, innovation indicators may lose most of their information content when used as targets for firms, universities or policy (Freeman and Soete, 2009; Nelson 2009). Suppose you are the CEO of a technology firm and ask your employees to increase the number of product innovations, possibly even give them positive incentives to do so, e.g. additional research budget. Then, the employees will develop strategies to produce as many product innovations as possible and might overlook or not consider other kinds of innovation. This would be detrimental to the innovation process as the different kinds of innovation often support each other. Second, innovation indicators have different meanings for developing and developed countries which makes cross-country comparisons tricky at best (Freeman and Soete, 2009).

The disadvantages of innovation indicators and their strategic use do not mean that we should not use them (cf. this and the following Nelson, 2009). No, but it is important to use them carefully by considering their potential disadvantages and their potential strategic use. Moreover, the analysis of several indicators helps to get a better picture. So does the use of quantitative indicators in combination with qualitative ones.

1.2.2 European Innovation Scoreboard

Once a year the European Commission publishes the European Innovation Scoreboard (European Commission, 2020). It compares innovation performance of EU countries, and other countries by assessing relative strengths and weaknesses of national innovation systems with the help of innovation indicators. Based on that it provides advice on what the different countries should do in the future.

The European Innovation Scoreboard 2018 has been severely criticised for the way it uses innovation indicators (Edquist et al., 2018). Particularly, Edquist et al. (2018) disapprove of the fact that the relationship between input and output indicators has been considered insufficiently. In their eyes this invalids the conclusions drawn on the basis of the analysis of the European Innovation Scoreboard 2018. To give an example, Edquist et al. (2018) claim that Sweden is only considered an innovation leader because of its high innovation input, while the lack of corresponding innovation output is insufficiently considered.

Video:

https://www.youtube.com/watch?v=9qr5gJP1j7U&feature=youtu.be

Readings for Chapter 1.2:

European Commission (2023): EU Innovation Scoreboard 2023.

https://op.europa.eu/en/publication-detail/-/publication/04797497-25de-11ee-a2d3-01aa75ed71a1/language-en

Edquist, C., Zabala-Iturriagagoitia, J. M., Barbero, J. & Zofío, J. L. (2018) On the meaning of innovation performance: Is the synthetic indicator of the innovation union scoreboard flawed? *Research Evaluation*, 27(3)**,** 196-211 https://charlesedquist.files.wordpress.com/2018/05/rvy011.pdf.

Freeman, C. and L. Soete (2009): Developing science, technology and innovation indicators: What we can learn from the past, in: Research Policy, 38, 583-586: http://dx.doi.org/10.1016/j.respol.2009.01.018

Nelson, A. J. (2009). Measuring knowledge spillovers: What patents, licenses and publications reveal about innovation diffusion. Research Policy, 38(6), 994-1005. doi: http://dx.doi.org/10.1016/j.respol.2009.01.023

2. Innovation Systems and Proximity

Dr. Claudia Werker

2.1 The Linear Model of Innovation Revisited

The linear model of innovation has been severely criticized in the past. Yet it is important to know it, because it has been widely used amongst researchers, managers and policy makers. So, in order to participate in a discussion with them you will need to understand the linear innovation model.

Figure 1: The linear model of innovation inspired by Godin (2006).

The linear model of innovation comprises four stages driven by different agents (see Figure 1).

The first stage '*basic research*' reflects the idealization of intellectual work in terms of basic research stemming from the political rhetoric (Godin, 2006). The idea is that researchers carrying out basic research detect fundamental knowledge, in particular better understand the laws underlying the functioning of nature (Balconi et al., 2010). The second stage '*applied research*' reflects the goals of industry (Godin, 2006). When researchers carry out applied research they still aim at the acquiring new knowledge but do this with specific practical use of its results in mind (Balconi et al., 2010). The third stage '*development*' was actually added by statisticians (Balconi et al., 2010; Godin, 2006), e.g. in the very influential Frascati manual. In this stage researchers build on existing knowledge directed to innovation in terms of new products, processes, services or systems. These innovations were included by economic analysts as the fourth stage '*innovation*' (Balconi et al., 2010; Godin, 2006).

Critics have been pointing out the advantages and disadvantages of the linear model including the notion of basic versus and applied research. The beauty of the linear model of innovation lies in its clear cut stages which designate specific roles to the various agents in the creation and dissemination of knowledge and innovation. It suggests

"… a clear division of labour along the sequence among different types of agents who specialise in the various relevant stages. Typically, basic research is conducted in universities and public laboratories, while applied research and technological development are carried out by firms ..." (Balconi et al., 2010, p. 5).

The linear model of innovation has always been heavily criticised, because it comes with a number of substantial problems (cf. this and the following Balconi et al., 2010; Godin, 2006): The linear model of innovation neglects that there are

- linkages between the different stages,
- non-linear processes driving research,
- bottlenecks in creating and disseminating knowledge, as well as
- various agents interacting.

This criticism has led to revised versions of the linear model of innovation (e.g. Balconi et al., 2010). In particular, further developments of stages of the innovation processes and inter-linkages have added number and nature of relationships of various agents to the picture. Eventually this has led to several new approaches which take the relationships between agents and their embeddedness in an institutional and cultural context seriously. One of them is the approach of innovation systems (see Chapters 3.2 to 3.4 for details).

While feedbacks loops between the different stages of the linear model of innovation are crucial on a systemic level, e.g. that problems in the 'development' and 'innovation' might lead to more fundamental questions fed back to the stages 'basic research' or 'applied research', it is important to realize that individual researchers, particular university departments or private R&D laboratories might follow a linear path when carrying out their research (Balconi et al., 2010).

Video:

https://www.youtube.com/watch?v=kqTYpXL8riY&feature=youtu.be

Readings for Chapter 2.1:

Balconi, M., Brusoni, S., & Orsenigo, L. (2010). In defence of the linear model: An essay. *Research Policy*, *39*(1), 1-13. http://dx.doi.org/10.1016/j.respol.2009.09.013

Godin, B. (2006). The Linear Model of Innovation. The Historical Construction of an Analytical Framework. Science, Technology and Human Values, 31(6), 639-667. http://dx.doi.org/10.1177/0162243906291865

2.2 Defining Innovation Systems

Innovation systems consist of three major elements, i.e. institutions, innovative agents and the relationships between them (cf. this and the following e.g. Edquist, 2011). *Institutions* refer to formal (e.g. laws) and informal rules (e.g. codes of conduct, i.e. a set of rules for an organization). *Innovative agents* (see Section 2.3) can come from different backgrounds, most importantly from the industrial, academic or governmental sector, e.g. firms, universities, ministries. The functioning and the results of an innovation system also depend crucially on the *relationships* between innovative agents. It is important that they exchange knowledge and innovation, communicate about research problems and questions and jointly carry out research.

Please note that a number of concepts cover similar aspects as the innovation systems approach, e.g. the triple helix approach (e.g. Etzokowitz & Leydesdorff, 2000).

Video: https://www.youtube.com/watch?v=LHHU9axgETw&feature=youtu.be

Readings for Chapter 2.2:

Edquist, C. (2011). Design of innovation policy through diagnostic analysis: identification of systemic problems (or failures). Industrial and Corporate Change, 20(6), 1725-1753. http://dx.doi.org/10.1093/icc/dtr060, Chapters 2.1. & 2.2.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and ''Mode 2'' to a Triple Helix of university–industry–government relations. Research Policy, 29, 109-123, http://dx.doi.org/10.1016/S0048-7333(99)00055-4

2.3 Agents and Stakeholders

In innovation systems you find agents and stakeholders. *Innovative agents* carry out research, collaborate and communicate in processes of innovation and technological change; they act. In contrast, *stakeholders* are only subject to changes emerging from innovation and technological change.

This distinction is particularly important when discussing responsible innovation (European Commission, 2013). Stakeholders might have vested interests in innovation processes, e.g. in cases when their privacy is at stake. However, agents might not consider these interests, as they do not have incentives to do so, at least not in the short run. Yet in the long run this lack of consideration can backfire. A good example of this is the patient cards in the Netherlands:

> "Many countries across Europe are considering the introduction of Electronic Patient Record Systems, but privacy concerns are widely seen as an obstacle to their development and use. The Dutch government invested about €300 million in the development of an EPR system that provides summaries from healthcare records for the purpose of exchanging medical information nationwide. However, the upper house of the Dutch parliament rejected the proposal to introduce the EHR because there have been strong concerns whether this system sufficiently takes into account aspects of privacy control (..). Responsible Innovation and Research would have made it possible to accommodate privacy concerns in the design of the system." (European Commission, 2013, p. 63)

In the following, we concentrate on those agents mainly driving innovation and technological change, i.e.academic, industrial and governmental agents. Depending on the circumstances these agents can also be stakeholders. Please note that recently civic communities, sometimes called civic entrepreneurs, have become important innovative agents in specific areas as well, e.g. in the energy sector (Werker et al., 2017). Examples are so-called prosumers, i.e. households producing energy, e.g. with the help of a photovoltaic system on their roof, and using it for their own purposes.

In contrast to what the linear innovation model suggests *universities* go well beyond doing basic research (cf. this and the following e.g. Fromhold-Eisebith & Werker, 2013): They provide knowledge regionally, (nationally and internationally). They have the potential to foster and generate human capital and entrepreneurship. They are nodes of intra- and inter-regional linkages in regional, national and international knowledge networks. And last but not least, universities provide additional employment, innovation and technological change.

The terms innovation, entrepreneurship and industry are often used in one breath. We already discussed innovation in Chapter 1. One possible definition of *entrepreneurship* is that it "… "… is the process by which new enterprises are founded and become viable …". (Vivarelli, 2013, p. 1456). Please note that entrepreneurship also takes place within larger and within incumbent companies, thereby covering *industry* as a whole. Moreover, it can also take place in the academic and governmental sector (Etzkowitz & Leydesdorff, 2000). For more details on industrial entrepreneurship please refer to Vivarelli (2013).

Traditionally the *government* has been considered as providing the knowledge infrastructure, particularly universities of applied sciences and schools. However, the government goes well beyond this by providing subsidies for research and development, by public procurement, by advising and guarding the stakeholders' interests (Etzokowitz & Leydesdorff, 2000; European Commission, 2013).

Video:

https://www.youtube.com/watch?v=JwTfYWNEOVQ&feature=youtu.be

Readings for Chapter 2.3:

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and ''Mode 2'' to a Triple Helix of university–industry–government relations. Research Policy, 29, 109-123, http://dx.doi.org/10.1016/S0048-7333(99)00055-4

European_Commission. (2013). *Options for Strengthening Responsible Research and Innovation*. Luxembourg: European Commission Retrieved from ISBN 978-92-79-28233-1. http://dx.doi.org/10.2777/46253

Fromhold-Eisebith, M., & Werker, C. (2013). Universities' functions in knowledge transfer: a geographical perspective. The Annals of Regional Science: http://dx.doi.org/10.1007/s00168-013-0559-z

Vivarelli, M. (2013). Is entrepreneurship necessarily good? Microeconomic evidence from developed and developing countries. Industrial and Corporate Change, 22(6), 1453-1495. http://dx.doi.org/10.1093/icc/dtt005

Werker, C., Ubacht, J. & Ligtvoet, A. (2017) Networks of entrepreneurs driving the triple helix: Two cases of the dutch energy system. Triple Helix, 4(4), 1-25, http://dx.doi.org/10.1186/s40604-017-0047-z.

2.4 Proximity: Relationships

As indicated before (see Chapter 2.2) relationships between innovative agents are crucial for the functioning and output of innovation systems. In particular, this holds for collaborations as they foster the creation and transfer of knowledge and innovation. *Proximity* between collaboration partners either enables or hampers collaborations (cf. this and the following Werker et al., 2016, Lazzeretti & Capone, 2016, and Ooms et al., 2018). Particularly geographical, organizational, institutional, cognitive, social and personal proximity does so in various combinations and ways. Please refer to Table 2 for an overview and to Werker et al. (2016) for more details.

Proximities	Distinct attributes[a]	Level of analysis
Geographical	Location (pure physical distance)	Macro and meso (international/national/global/local)
Institutional	Formal and informal rules & regulations imposed by specific administrative geographical territories, such as countries and regional entities, including cultural aspects	Macro (nation/region)
Social	Embeddedness in knowledge fields, professional associations or social communities	Meso (networks)
Organizational	Organizational objectives and organization-specific formal and informal rules & regulations (including aspects of organizational culture)	Meso (organizations)
Cognitive	Knowledge areas of expertise and experience as well as reputational standing	Micro (individual)
Personal	Personal character traits, behavioural patterns, and enjoyment of one another's company	Micro (individual)

[a] Adapted, revised and extended based on Caniëls et al. (2014, p. 232) and Boschma (2005, p. 71)

Table 2: Different kinds of proximity (Werker et al., 2016), p. 3

Video:

https://www.youtube.com/watch?v=0fFdiLt1Q3E&feature=youtu.be

Readings for Chapter 2.4:

Lazzeretti, L., & Capone, F. (2016). How proximity matters in innovation networks dynamics along the cluster evolution. A study of the high technology applied to cultural goods. *Journal of Business Research*, *69*(12), 5855-5865. http://dx.doi.org/10.1016/j.jbusres.2016.04.068

Ooms, W., Werker, C. & Caniëls, M. (2018) Personal and social proximity empowering collaborations: The glue of knowledge networks. Industry and Innovation, 1-8, http://dx.doi.org/10.1080/13662716.2018.1493983

Werker, C., Ooms, W., & Caniëls, M. C. J. (2016). Personal and related kinds of proximity driving collaborations: a multi-case study of Dutch nanotechnology researchers. SpringerPlus, 5(1). http://dx.doi.org/10.1186/s40064-016-3445-1

2. Technological and Sectorial Innovation Systems

Dr. Claudia Werker

3.1 Technological Innovation Systems (TIS), Sectors and Markets

Technology is know-how on how to combine resources in order to produce products and services that help the recipients solving socio-economic problems. Technological innovation systems (TIS) focus on " … how the innovation system around a particular technology functions." (Bergek et al., 2015) They focus on mature technology fields and on the arrival and diffusion of new and radical innovation. "A sector comprises multiple TISs supplying technologies and products needed to serve a certain function for prospective users. Interaction takes place due to sector specific regulations, norms and cognitive frames, and physical infrastructures." (Bergek et al, 2015, p. 61)

While TIS is a technology-centred framework, it is also a systems approach (cf. this and the following Bergek et al., 2015). This means that TIS captures the agents, institutions and functions of a specific technology. At the same time it is important to realize that TIS is always also related to other systems (contexts), i.e supportive or competitive relationships to other TISs, relationships to sectors, relationships in the context of a geographical dimension (regional, national and/or global) and relationships to the political sphere where institutions are discussed and set up.

Video:

https://www.youtube.com/watch?v=hlYFjSF0VqA&feature=youtu.be

Readings for this Chapter:

Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., & Truffer, B. (2015). Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. Environmental Innovation and Societal Transitions, 16, 51-64: http://dx.doi.org/10.1016/j.eist.2015.07.003

3.2 Cases of Energy Systems in the Netherlands and Russia

Readings for this Chapter:

Nevzorova, T. (2022). Functional analysis of technological innovation system with inclusion of sectoral and spatial perspectives: The case of the biogas industry in Russia. Environmental Innovation and Societal Transitions, 42, 232-250. http://dx.doi.org/10.1016/j.eist.2022.01.005

Werker, C., Ubacht, J. & Ligtvoet, A. (2017) Networks of entrepreneurs driving the triple helix: Two cases of the dutch energy system. Triple Helix, 4(4), 1-25, http://dx.doi.org/10.1186/s40604-017-0047-z.

3. Geographical Innovation Systems

Dr. Claudia Werker

4.1 Geographical Delineation of Innovation Systems

The original concept of innovation systems was about national innovation systems (Marxt & Brunner, 2013). Nowadays we distinguish innovation systems focusing on technology from innovation systems with a geographical delineation, i.e. regional, national or global innovation systems. Often the focus of technology and geography overlap, e.g. in the case of the software industry in Bangalore (Chaminade & Vang, 2008).

Delineating innovation systems geographically can be challenge. Doing so for national innovation systems is rather straight-forward, because you simply take the boundaries of a country to delineate it. There are good reasons for focusing an analysis on a national innovation system, in particular the same or similar formal and informal institutions, culture and language and often long-standing relationships between agents and stakeholders. At the same time innovative agents often relate to others either in units smaller than a country or beyond the national boundaries. Then, it might be more suitable to investigate a regional or global innovation system. Delineating regional innovation systems requires some considerations of how to draw boundaries, e.g. homogeneity or functionality of regions. Often we use what the statistical offices provide as delineations, because this approach makes it possible to underpin our analysis with quantitative data. An often used delineation of regions are the NUTS (Nomenclature of Territorial Units for Statistics) regions (for details refer to Eurostat, 2018). Looking into global innovation systems can be a challenge as the number of potential relationships between innovative agents is immense and the global linkages might be sparse and concentrated. For that reason analyses of global innovation systems are very scarce.

Readings for this Chapter:

Eurostat (2018): NUTS - Nomenclature of territorial units for statistics https://ec.europa.eu/eurostat/web/nuts/background, last visited 24.08.2022

Marxt, C., & Brunner, C. (2013). Analyzing and improving the national innovation system of highly developed countries — The case of Switzerland. Technological Forecasting and Social Change, 80 (6), 1035-1049. http://dx.doi.org/10.1016/j.techfore.2012.07.008 , particularly Sections 1 and 2.

4.2 Agglomeration and Deglomeration Effects

Agglomeration and deglomeration relates to economies and diseconomies that are space-related. Generally speaking, economies of scale are cost-advantages. When firms increase their scale of operation the cost per unit of output decreases with increasing scale. Agglomeration effects are space-related economies of scale; deglomeration effects are space-related diseconomies of scale. Agglomeration effects mean that economic and innovative activities in close proximity to each other leads to cost saving. Deglomeration effects mean that spreading economic and innovative activities evenly across geographical space leads to cost savings. Agglomeration and deglomeration effects can take various forms, many of which are crucial to innovation processes and innovation systems, e.g. knowledge infrastructure and human capital.

The existence of agglomeration or deglomeration effects can be a reason to delineate innovation systems one way or the other. To give an example: If employee mobility is central for innovation and research for the technology you analyse and commuting relationships that go well beyond the borders of a city (e.g. the Randstad, the Netherlands, or Greater London and beyond) you might choose a larger area than a city only.

Video for 4.1 and 4.2:

https://www.youtube.com/watch?v=d58zzI_70sg&feature=youtu.be

Readings for this Chapter:

Ooms, W., Werker, C., Caniëls, M. C. J., & Van den Bosch, H. (2015). Research orientation and agglomeration: Can every region become a Silicon Valley? Technovation, 45-46(November-December), 78-92. https://doi.org/10.1016/j.technovation.2015.08.001, particularly Sections 2.2 and 2.3

4.3 Analysing Geographical Innovation Systems

In the following we cover the case of Bangalore in India, a regional innovation system concentrating on the software industry, and the Swiss national innovation system. Please read the papers carefully to learn how the concepts of Section 4.1 have been used. Based on that you can figure out how to use them for your own assignment.

4.3.1 The Case of Bangalore

Readings for this Chapter:

Chaminade, C. and J. Vang (2008): Globalisation of knowledge production and regional innovation policy: Supporting specialized hubs in the Bangalore software industry, in: Research Policy, 37, 1684-1696: http://dx.doi.org/10.1016/j.respol.2008.08.014

4.3.2 The Case of Switzerland

Readings for this Chapter:

Marxt, C., & Brunner, C. (2013). Analyzing and improving the national innovation system of highly developed countries — The case of Switzerland. Technological Forecasting and Social Change, 80 (6), 1035-1049. http://dx.doi.org/10.1016/j.techfore.2012.07.008

5. Responsible research and innovation

Dr. Udo Pesch & Dr. Claudia Werker (with thanks to Martin Sand for comments)

5.1 Responsibility of research and innovation

In a technological milieu engineers and designers fundamentally shape the world which we live in, which again has a tremendous impact on how well people can live in this world together and whether they flourish. Because of this, they have a big responsibility, which is hardly recognizable in the way that engineers and designers deal with their jobs, nor in the way that responsibility is arranged in formal and informal structures. In line with the linear model of innovation (see Chapter 2.1), engineers and designers are used to break down complex problems into manageable portions. Often they consider their responsibility to be constrained to the ‘discovery’ of new technology, not for its further societal uptake. This process of discovery is all about drawing problem boundaries that allow a specific engineering solution. It is often thought that the responsibility of engineers is primarily to provide the right solutions for posed problems. They are not appointed to question the origin of the problem, nor the application of the solution – these are, respectively, the delegated responsibilities of clients and of end-users. This traditional approach to engineering morality based on the linear model of innovation is captured in the slogan of the National Rifle Association: ‘guns do not kill people, people do’. Still, Mikhail Kalashnikov, the inventor of the AK-47 – the most lethal gun in history – stated just before he died that he was suffering ‘spiritual pain’ about the question whether he was responsible for the deaths by the weapons he created.

The fact that engineers share responsibility for the use of the technologies they have designed does not imply that engineers are to be blamed for each and every negative result of the application of their designs. The effects of new technologies depend on their use after implementation. This makes it hard to predict the effects of new technologies and to do something about their negative effects once these have become manifest. This insight has given rise to the ‘control-dilemma’ introduced by David Collingridge (Genus and Stirling, 2018). It states that the possibility to steer a technology is greatest in the early stages of its introduction, whereas knowledge about the effects of this technology is greatest when the technology has become fully embedded in society. This dilemma gives rise to the demand of improving our anticipatory capacities and govern technological developments until and after its diffusion in a way that helps to prevent failure and catastrophe.

5.2 Responsible research and innovation: process versus outcome

To cope with the ethical challenges of technology development introduced above the notion of *responsible research and innovation* (RRI) has been developed in recent years. “[I]n an ideal situation, responsible innovation can best be conceptualized as an endorsement of the relevant values during the innovation process" (Taebi et al., 2014, p. 118). This idea has quickly gained prominence in academic and policy circles (Owen et al., 2012). The aspiration is that by having innovations (processes) that are more responsible, more ethically and socially acceptable technologies will be developed and a new "social contract for innovation" can be established.

To suit the complexities of research and innovation, the concept of responsibility needed revitalization (Owen et al., 2012). Some approaches on RRI have focused more on the *process*, others more on the *outcome*. When focusing on the process, the questions is how innovative activities can lead to output that is societally desirable by being anticipatory, reflective, deliberative and responsive (Owen et al., 2012). Focusing more on output, the question is how to include values in such a way that the result is societally acceptable (Taebi et al., 2014). At the end of the day, research and innovation is an evolutionary process where the innovative output of one process becomes the input and starting point for the next process (Owen et al., 2012).

Differences in the process and outcome oriented approaches of RRI depend on the scope of technologies analysed. Researchers looking at the values related to the output of a technology tend to address rather concrete domains of engineering, such as shale gas (e.g. Dignum et al., 2015), while the scholars emphasizing processes especially look at technologies that are not yet so developed, such as nanotechnology (e.g. Nordmann, 2014), which eludes identifying specific governance and design choices.

The *process-oriented approach of RRI* aims at informing and instructing scientists and technology developers to improve their innovation activities so that the eventual results of their work is societally acceptable. RRI entails a collective and continuous commitment to be anticipatory, reflective, deliberative and responsive (e.g. Owen et al., 2012: Anticipatory means to investigate alternatives to identify issues, impacts and implications. Reflective means that innovative agents and other stakeholders consider their own and others' purposes and motivations as well as uncertainties and risks. Deliberative points at innovative agents opening up their insights and dilemmas by talking to each other and other stakeholders. Thereby, they are able to include all relevant perspectives and to identify potential conflicts of interests. Responsive means that innovative agents keep communicating with each other and other stakeholders in an open, iterative and inclusive process that influences the direction and pace of the innovation process. These four dimensions of the process oriented approach of RRI can also be seen as guiding principles that have to be taken into account when working on a new technology.
The *output oriented approach of RRI* revolves around the public values that need to be 'designed' into the technology. It builds on the ideas about value-sensitive design (VSD) from the field of ICT-development, which aims at embedding certain values like privacy and security as intrinsic design requirements of ICT-systems. The starting point of VSD is to take this idea and apply it in other fields of technology

development, and design a broad range of public values into technologies so that they become more desirable.

5.3 Accountability frameworks for active responsibility of engineers

In this course, we will be on the lookout for finding an accountability structure that guides engineers in their design choices. Without having a designated public, individual technology developers are at a moral loss; they have no way to morally calibrate their activities, while their work may have a huge impact on society. With that, the potential moral burden of an engineer can be huge, unmanageable even. It is not surprising that they try to evade thiss moral burden by appealing to the linear model that suggests that engineers are merely applying science-based knowledge.

Discarding the linear model means that technology developers can employ a new way of understanding and extending their agency in innovation and find a different way of finding meaning to their world. Active care about our shared world – which is a forward-looking responsibility – can be seen as the only way to overcome the impossibility to account for decisions in a backward-looking fashion (Pesch, 2015). It needs to be emphasized that such care is not just an active responsibility of an individual, but it has to be embedded in a society that is prepared to undergo change.

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6. Responsible Research and Innovation (RRI) Systems

Dr. Claudia Werker

Recent disruptions caused by the digital age and increasing calls for RRI have overturned supposed certainties of how to assess research and innovation. Particularly, privacy issues as well as the risk of discrimination and manipulation severely increase in the digital age. Simultaneously, big data and internet of things solutions offer multiple opportunities of following research and innovation processes more closely, thereby offering chances to integrate the values of *all* stakeholders.

Videos:

https://www.youtube.com/watch?v=dGGayYzLSRQ&feature=youtu.be

https://www.youtube.com/watch?v=VI2Qp_D1KfE&feature=youtu.be

https://www.youtube.com/watch?v=GauvZRC8CW4&feature=youtu.be

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7. Inclusive Research and Innovation (IRI) in STEM

Dr. Claudia Werker

7.1 Exclusion of Stakeholders because of STEM's diversity-oblivion

Exclusion of stakeholders happens, because usually agents do not address the diversity of human beings in a systematic way (Caroline Criado Perez, 2019; Werker, 2021a). Most agents consider representative human beings in their research and innovation activities and outcomes, i.e. some kind of average white man (C.C. Perez, 2019). In human-robot-interaction Seaborn, Barbareschi, and Chandra (2023, p. 1) found

> "… evidence of limited, obscured, and possible misrepresentation in participant sampling and reporting along key axes of diversity: sex and gender, race and ethnicity, age, sexuality and family configuration, disability, body type, ideology, and domain expertise."

Also in virtual realities used for entertainment, the focus on male players bothers female players (C.C. Perez, 2019): Headsets do not work when wearing Mascara. And male designers forgot to disable opportunities of virtual sexual abuse in virtual reality worlds to start with.

There are three major reasons why agents are diversity oblivious. The first reason is STEM education as such. While responsible anticipation of emerging technologies and their socio-ethical implications for engineering education have been discussed (van Grunsven, Stone, & Marin, 2023), they have been rarely implemented. The second reason for agents using diversity-oblivious approaches is an exceptionally long tradition of saying human and meaning 'white man' when collecting, analysing, and reporting data. This tradition dates back to the first efforts made to systematically collect data in the 19th century and well before that (D'ignazio & Klein, 2023). The third reason for diversity-oblivion of STEM research and innovation are notions of 'objectivity', thereby ignoring subjective elements of decision-making and problem-solving that are based on heuristics. When dealing with a wealth of information and alternative choices, heuristics is a strategy for agents to store and process a limited number of them (Dale, 2015). "However, whilst heuristics can speed up our problem-solving and decision-making processes, they can introduce errors and bias judgements" (Dale, 2015, p. 1). Agents choose who is important for research and innovation, what is interesting and which groups of society to serve. In particular, they determine whether or not to include diverse human beings in their research questions, methodologies, reporting, impact, and innovation (Werker, 2021b).

Also agents explicitly aiming at helping disadvantaged groups might miss their goals. An example is techno-ableism where engineers and designers aim at supporting disabled human beings yet "… reinforcing ableist tropes about what body-minds are good to have and who counts as worthy (Shew, 2020, p. 43). If well-meaning designers and engineers usually pre-scribe exoskeletons as the solution to people who is not able to walk upright, this is not necessarily what they have in mind as the best solution for themselves (Shew, 2020). Consequently, these solutions still leave room for improvement and might be even completely off the mark, thereby falling short of using STEM's potential to its fullest extent.

7.2 Beyond Gendered Research and Innovation: IRI in STEM

Including stakeholders requires STEM agents to overcome its diversity-oblivion by particularly considering the values of diverse stakeholders usually excluded yet affected. Agents embracing diversity as a driver of research and innovation allow for value-driven, time-consuming processes that are in-efficient in the short-term but critical in the long-run.

While gendered research and innovation has been a valuable step to include sex and gender in STEM research and innovation, the general uptake remained disappointing. Most prominently, ever since 2014, i.e. the launch of the Framework Programme Horizon 2020, the European Commission has been promoting and supporting gendered research and innovation (European_Commission, 2020). With the help of its research funding schemes Horizon 2020 and its follow-up Horizon Europe, the European Commission has been stimulating agents to conduct gendered research and innovation projects. As a consequence, there are quite some examples of gendered research and innovation projects in STEM. There are e.g. fifteen cases from various STEM disciplines (Directorate-General for Research and Innovation, 2019) and several new methods to embed gender and sex as well as other social factors intersecting with them in STEM to show for (e.g. Tannenbaum, Ellis, Eyssel, Zou, & Schiebinger, 2019). Particularly in health sciences, agents in STEM have been using the potential of gender and sex diversity for driving scientific discovery and innovation (Nielsen, Bloch, & Schiebinger, 2018). Still, there are many examples where also health sciences fall short of fully considering women in their research and innovation (Nielsen et al., 2018; Werker, 2021a).

To fully acknowledge diversity beyond the men-women divide, agents must consider all social categories including combinations of them. The social categories include gender, age, race, disability, sexual orientation, social class and others (Rice, Harrison, & Friedman, 2019; Seaborn et al., 2023). By acknowledging this broad spectrum of the diversity of human beings, agents would use diversity to its fullest extent for driving scientific discovery and innovation. To get a full picture, agents would need to use intersectionality for their research and innovation activities as well. Intersectionality points to people being underprivileged because of a combination of social categories (cf. this and the following Crenshaw, 2013; Rice et al., 2019).

Initially, this concept was used in the context of sex and race. Yet in the meantime, it has been considered for all kinds of combinations, such as gender, sex and age or race and socio-economic background. I broaden the definition of gendered research and innovation beyond gender and sex to fully account for diversity of human beings in STEM research and innovation, i.e.

> *Agents conducting inclusive research and innovation in STEM explore and exploit the potential of the diversity of human beings in all its facets to drive scientific discovery and innovation.*

7.3 STEM Cases with IRI in STEM elements

7.3.1 Medical Sciences

To take an alternative approach towards inclusive medical science would require to leave the one-size fit it all approach behind (cf. this and the following Werker, 2024b). This comes with huge challenges regarding ethics and methodology, as Irene Grossmann (Delft University of Technology), who has been particularly working on oncology, explains: In the current practice of evidence-based research agents exclude many patients from the trials, such as patients with co-morbidities. These are often the very patients in need of diagnoses and treatment developed. So, as an alternative approach Grossmann included all patients in her trials, finding considerably more complications. Informally, colleagues confirmed that this would be the same for them – had they chosen the same approach. Yet they bend to the rules of the existing innovation system to stick to evidence-based research as it was established.

7.3.2 Automobile Engineering

Cornelia Lex, Corinna Klug, and Mario Hirz (Graz University of Technology) have been aiming at safety and comfort for all drivers and passengers. Whenever they have to use human beings in their research set-ups, this is cost intensive. Therefore, in many cases they use a combination of trials with human beings and simulation models. Yet the trials with human beings are necessary to train simulation models. In safety of automobiles, interdisciplinary collaborations do not only help with developing more diverse crash-test dummies, they also point at solutions for safety beyond diverse crash-test dummies (cf. this and the following Werker, 2023). Lex, Klug and Hirz have been particularly collaborating with colleagues from the medical sector, because these colleagues know the characteristics of car injuries and can help changing automobiles accordingly. In addition, they have been collaborating with psychologists, because human behaviour of drivers and passengers also affects their safety. To give an example, the older people get the less they react to signals other than sound. This is important to take care of when building safety systems supporting drivers.

To use diverse crash-test dummies more broadly another institutional set-up would be necessary than the current one. Current EU regulations do not require that car manufacturers use diverse crash-test dummies to test the safety of cars. Yet things are changing. Only very recently, the European Commission published a study on inclusiveness of anthropometrics, i.e. human body measurement and analysis (European_Commission, 2024), in European harmonised standards which will serve as the basis for ensuring " … the safety of products by aligning them with EU legislation's health and safety requirements" (European_Commission, 2024). If and when these standards are implemented for cars, industry has to follow suit.

7.3.3 Algorithms Technology and Mathematics

Changes in the research and innovation process, particularly methodology, as well as interdisciplinary collaborations play a huge role in avoiding or overcoming biased algorithms (cf. this and the following Werker, 2024a). As Claudia Wagner (RWTH Aachen University) explains Bigtech companies play a huge role in developing algorithms and usually do not disclose the manner they programme them. To avoid biased algorithms, she suggests collecting and analyse large datasets with people with diverse backgrounds as the gold standard. This is expensive. It would be important not to leave the funding to Bigtech companies only, because while collecting data in the way suggested by Wagner is in the public interest, it does not necessarily align with the economic goals of the Bigtech companies. In her research of developing unbiased algorithms, Wagner relied on interdisciplinary research. She has been collaborating with social scientists helping her to understand the emergence of biases and how to deal with them.

7.4 Towards Innovation Systems Supporting IRI in STEM

7.4.1 Inclusion of Stakeholders and changing Institutions

In all three cases (Section 7.3), agents included stakeholders excluded yet affected. This approach changed the whole research and innovation process, i.e. the research questions, methodologies (data collection and their analysis), and ways to report. In particular, agents in these cases provided inclusive solutions for patients and drivers usually excluded from trials and test-runs and ways to prohibit or overcome discrimination when using algorithms. Dealing with the consequently larger and more diverse datasets is a challenge because of costs and of necessary changes in analysing the data.

Initiatives by policy in changing institutions can be crucial. Only recently the European Commission published a study requiring anthropometric features, i.e. the systematic measurement of the physical properties of the human body, being considered for harmonised standards for safe and secure products in the European Union (European_Commission, 2024). If this initiative is translated into EU directives and national laws, we can expect the automobile industry to follow suit. Similar initiatives would help in inclusive medical research and healthcare. As in the case of inclusive algorithms we see a global innovation system, institutional solutions seem less likely. As Wagner points out, counterbalancing the power of Bigtech companies not disclosing the programming and training of their algorithms can be achieved by funding the collection and analysis of large datasets (Werker, 2024a). Those are so expensive that they goes beyond the scope of normal university funding. Public funding would help university researchers to build a body of knowledge of how to avoid or overcome biased algorithms.

7.4.2 Knowledge Creation and Learning in an interdisciplinary Way

In two out of the three cases presented in Section 7.4.1, agents included stakeholders usually excluded yet affected by changing the way they created knowledge and learned. In particular, Grossmann investigated the experience of patients in her trials in much more detail (Werker, 2024b); so did Lex, Klug and Hirz in their experimental set-ups with drivers (Werker, 2023). This gave them information to produce more inclusive solutions.

In all three cases, agents relied crucially on interdisciplinary collaborations. In the case of inclusive medical research and healthcare, Grossmann collaborated with other STEM researchers, in particular mathematicians. In all cases, agents collaborated with colleagues from social sciences and humanities in order to understand the nature of diversity of human beings relevant for their discipline, particularly of how to deal with values of stakeholders. Interdisciplinary collaboration between social sciences and humanities and STEM seems to be a core enabler of inclusive innovation systems.

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Further listenings for this chapter
https://podcasters.spotify.com/pod/show/iri-in-stem: in particular the following:

- *Diversity of crash test dummies? Safety and security in automobiles*
- *Inclusive Algorithms for a Juster World*
- *Inclusive Medical Research and Health Care*

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