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Quadruple helix as a network of relationships: creating value within a Swedish regional innovation system

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\textbf{ABSTRACT}

A regional smart specialization initiative is investigated from a quadruple helix framework (industry, government, academia, and users/civil society). Based on a qualitative case study, we examine the interdependencies of actors, resources, and activities from a micro perspective. The aim is to understand the relationships and the value created between the different actors. From the results we conclude that the fourth helix should be viewed as a whole – an arena where triple helix actors in different value adding relationships take on different roles – where they create value to civil society, for example, new jobs or products for improved elderly care. In line with this, we state that the fourth helix is far more complex than limiting it to simply become a fourth separate helix of users or civil society. Users in the quadruple helix framework can also be defined in several ways depending on the context of the arena (the fourth helix) and what value adding activities they bring to civil society. Thus, users can be businesses, organizations, citizens, society, and many more things.

\textbf{ABSTRAIT}

Une initiative de spécialisation intelligente régionale est examinée à travers un modèle à quadruple hélipe (industrie, gouvernement, milieu universitaire et utilisateurs/société civile). En nous basant sur une étude qualitative de cas, nous explorons les interdépendances des acteurs, des ressources et des activités dans une micro-perspective. Notre objectif est de comprendre les relations et la valeur créée entre les différents acteurs. Nos résultats nous amènent à conclure que la quatrième hélipe doit être prise en compte dans son ensemble – une arène dans laquelle des acteurs à triple hélipe engagés dans des relations à valeur ajoutée jouent des rôles différents – y créant de la valeur pour la société civile, par exemple de nouveaux emplois ou de nouveaux produits pour une amélioration des soins aux personnes âgées. Conformément à cette approche, nous affirmons que la quatrième hélipe est bien plus complexe que si elle se limitait à devenir simplement une quatrième hélipe distincte composée d’usagers et de membres de...

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la société civile. Une de ses complexités est qu'elle est composée à la fois de différents usagers (incluant aussi des triples acteurs) et de membres de la société civile. Dans le modèle à quatre hélices, les usagers peuvent être définis de plusieurs manières, selon le contexte de l’arène (la quatrième hélice) et les activités d’ajout de valeur qu’ils apportent à la société civile. Aussi, les usagers peuvent-ils être des entreprises, des organisations, des citoyens, la société et bien d’autres choses.

1. Introduction

Creating an environment where entrepreneurship and innovation can thrive has been a priority for decision makers and politicians. This is largely because innovation and entrepreneurship are seen as ways to create new jobs and also increase the standard of living with new and improved products and services. Creating regional innovation systems (RISs) and also forming an understanding of how these innovation systems work has been emphasized (Cooke, Uranga Gomez, and Etzehbarria 1997). In the EU 2020 strategy, the European Commission highlights that each RIS should be based on the specific knowledge located in a region, where each region builds on its own unique strengths and knowledge in the context of regional innovation strategies (European Commission 2012). Part of the EU strategy is an idea that there will be a regional advantage in the uniqueness of the region and the firms through collaborating innovation (Nordberg 2015).

Most studies are in agreement that proximity between key actors in an innovation system is important for knowledge transfer because the knowledge in the innovation processes is difficult to transfer to other places (Asheim and Isaksen 2002; Li et al. 2016). These studies have focused on the actors, often from a triple helix perspective, that make a distinction between actors from (1) academia/universities, (2) government, and (3) industry (Etzkowitz and Leydesdorff 2000; Ranga and Etzkowitz 2013; Strand, Ivanova, and Leydesdorff 2016) or from a quadruple helix perspective that also includes a fourth helix of the users and civil society (Höglund and Linton 2018; Leydesdorff 2012; McAdam et al. 2012). When it comes to the quadruple helix model, the inclusion of users and civil society has been highlighted as critical for the development of a RIS (Kriz, Bankins, and Molloy 2018).

Some researchers suggest that the results from the triple and quadruple helix studies have not yet delivered the expected results (Miller, McAdam, and McAdam 2016). Most studies have taken a macro perspective, and therefore not accounted for understanding the complexity of these research models and value-creating activities on a micro level (McAdam and Debackere 2018). Recent calls have suggested to research the quadruple helix from a micro perspective, and more specifically, its dynamic relationships, synergies, collaborations, coordinated environments, and value-creating activities (Cunningham, Menter, and O’Kane 2018; Edquist 2011; Höglund and Linton 2018; McAdam et al. 2012). As Kriz, Bankins, and Molloy (2018) state, it is important to delve deeper into the micro aspects of relationships in the quadruple helix model to enhance our understanding of dynamic relationships within a quadruple helix.
In this paper, we take the perspective of the quadruple helix as a network of relationships. By studying the interdependencies of actors, resources and activities from a micro perspective, we aim at enhancing our understanding of value creation and the relationships between actors, resources, and activities in the quadruple helix model. In line with this, we address the following research question: How do relationships in a quadruple helix setting – actors, resources and activities – contribute to value creation? In this way, the paper aims to contribute to the quadruple helix literature by offering a micro-based view of a RIS initiative in Sweden. We conclude that to fully understand the complexity of the quadruple helix model we need to go beyond conceptualizing the fourth helix as the user/end user and also address the fourth helix as a whole (an arena) where societal value creation is generated by the dynamic relationships (activities, resources, and actors) between academia, industry, and government.

2. Theoretical background

2.1. Quadruple helix

The quadruple helix model can be seen as an enhancement of the triple helix perspective that not only focuses on the actors from academia, government, and industry, but also recognizes the increased role played by civil society (Leydesdorff 2012). The main part of the literature, so far, agrees upon that it is important to extend the triple helix model with a fourth helix, but there is some confusion in regard to what this fourth helix could consist of (Carayannis and Rakhmatullin 2014; Höglund and Linton 2018; Nordberg 2015).

For example, Carayannis and Campbell (2012) conceptualize the fourth helix as media, culture, and civil society, arguing that that the fourth helix is human-centered and focuses on democratic knowledge, and in favor of arts, artistic research, and arts-based innovation (Carayannis and Campbell 2014). Similarly, Kriz, Bankins, and Molloy (2018) take an end user perspective of the fourth helix including, for example, public members embedded in the artistic and cultural fabric of a community. Likewise, Nordberg (2015) argues that the fourth helix is generally defined as the values, culture, and general backdrop to innovation processes. Ivanova (2014) also talks about the cultural aspects but from a system approach focusing on infrastructures, arguing that the quadruple helix model not only addresses the consumer but also the infrastructures of mass media, TV, radio, internet, and other possible means of mass communications. In this way, the author argues for both a civil society approach and an end-user approach. Similarly, Höglund and Linton (2018) argue that the fourth helix should not only be viewed as a separate helix but also as a context of the society as a whole and civil societal goals.

Arnkil et al. (2010) frame the quadruple helix as a user-oriented innovation approach. Carayannis and Campbell (2012) argue that the quadruple helix model places a strong focus on collaboration in innovation and, in particular, the dynamically intertwined processes. Following on this, Cunningham, Menter, and O’Kane (2018) take an end-user perspective and view the fourth helix as a further key stakeholder grouping within these innovation systems. Correspondingly, McAdam, Miller, and McAdam (2016) take a stakeholder perspective and address the innovation users as the fourth helix, acting in a meso-environment that captures the numberless of
relationships that take place between internal and external stakeholders. Similarly, Colapinto and Porlezza (2012) highlight that a core part of the fourth helix is related to the network, knowledge transfer, and human capital.

The relationship between knowledge production and networks in RISs and the fourth helix is discussed in several papers (see, e.g. Carayannis and Campbell 2009, 2014; Carayannis, Barth, and Campbell 2012; Carayannis, Campbell, and Rehman 2016; Grundel and Dahlström 2016; Kolehmainen et al. 2016; Lew, Khan, and Cozzio 2016). For example, Kolehmainen et al. (2016) place the quadruple helix framework at the very heart of knowledge-based regional innovation development. In relation to this, Carayannis and Campbell (2009) suggest a model called ‘Mode 3’ that focuses on the intertwined knowledge production in the innovation system and incorporates the fourth actor, civil society including media and culture, to form a Quadruple Helix Innovation System Framework (Carayannis et al. 2018a). Mode 3 comprises institutions and their social and natural systems and environments focusing on hybrid innovation networks and how knowledge clusters tie together different actors in the quadruple helices (see, e.g. Carayannis and Campbell 2006, 2009, 2010, 2011, 2014; Carayannis, Campbell, and Rehman 2016; Carayannis, Goletsis, and Grigoroudis 2018; Carayannis et al. 2018b; MacGregor, Marques-Gou, and Simon-Villar 2010; Schoonmaker and Carayannis 2013).

To sum up, there is no consensus on what the fourth helix is comprised of, but most researchers tend to address the fourth helix in terms of the civil society, consumer, and end user (Carayannis and Campbell 2009; Höglund and Linton 2018; McAdam et al. 2012; Miller, McAdam, and McAdam 2016). There is also more or less an agreement on the importance of collaboration in the quadruple helix model, putting the relationship aspects between the different helices in focus. In line with this, research has been conducted from a stakeholder theory perspective (see, e.g. McAdam, Miller, and McAdam 2016), a systems approach (see, e.g. Ivanova 2014; Nordberg 2015), the study of knowledge transfer (see, e.g. Colapinto and Porlezza 2012), as regional innovation management (Kriz, Bankins, and Molloy 2018), and from a Mode 3 model that highlights ecosystems (see, e.g. Carayannis et al. 2018a). All of these researchers have made significant contributions by their work, but what this literature stream could be extended by is also to incorporate a stronger focus on the relationship between the actors, resources, and activities within the quadruple helix setting.

2.2. Quadruple helix as a network of relationships

In this paper, we take the perspective of the quadruple helix as a network of relationships, where public and private organizations interact in value-creating processes to transform various inputs into valuable outputs for themselves and others. The emphasis in this paper is on the relational processes taking place within a quadruple helix setting, that is, the actors (public and private) involved, the resources combined, and the activities performed, as well as the outcome of the processes, that is, the perceived value by the actors involved in the network of relationships (cf. Hasche and Linton 2018). Besides the actors discussed in relation to the helices, this paper also discusses the hybrid organization that integrates, collaborates, and orchestrates the
various quadruple helix spheres to stimulate innovation (Champenois and Etzkowitz 2017). These hybrid organizations can, for example, be science parks and incubators that combine several institutional spheres. A unique feature of these hybrid organizations is that they are often autonomous and not accountable or controlled by one specific sphere (unlike, e.g. university incubators) (Champenois and Etzkowitz 2017). These hybrid organizations are seen as the glue that connects the many different actors within a quadruple helix network and acts as a catalyst between the actors. The relationships between the actors and a hybrid organization become a central issue in this paper.

Drawing on business network research and social exchange theory (see, e.g. Anderson, Håkansson, and Johanson 1994; Cook and Emerson 1978; Håkansson and Ford 2002; Håkansson and Snehota 1989, 1995), the relationships discussed are not viewed as created and developed in isolation. Instead, relationships are regarded as part of a broader context, that is, a network of interdependent relationships. These interdependencies are often discussed in terms of actors (public and private), resources, and activities as a way of understanding the substance of relationships (Anderson, Håkansson, and Johanson 1994; Håkansson and Johanson 1992; Håkansson and Snehota 1989, 1995). Håkansson and Johanson (1992, 129–130) argue that ‘actors are defined as those who perform activities and/or control resources. In activities actors use certain resources to change other resources in various ways. Resources are means used by actors when they perform activities.’

In this paper, the relationships (actors, resources and activities) are seen as the context that generates the conditions for creating value in a quadruple helix setting. Payne et al. (2008) describe the value-creating process as a series of activities performed and resources combined by different actors in order to achieve certain valuable outcomes, where value creation can be regarded as the essential purpose of different actors to engage in relationships. Before engaging in value-creating processes, actors have expectations regarding future collaboration in order to accomplish certain valuable outcomes and objectives of the organization. In some networks of relationships, all actors involved may share the same expectations as well as objectives. In others, the involved actors may individually formulate their expectations and goals. Through value creation processes, resources, and activities are combined by the interacting actors and new combinations developed, thereby enabling the actors to achieve something that none of the parties could have achieved alone (Hasche 2013). The value construct is often described as difficult to define due to the subjective aspects of evaluating the value created in relationships (de Chernatony, Harris, and Dall’Olmo Riley 2000). In this paper, we acknowledge that what is considered as a valuable outcome in a specific relationship by a specific actor is based on perceptions (van der Haar, Kemp, and Omta 2001) and that value is in the eyes of the beholder (Ulaga 2003).

3. Method

3.1. Case study

Since prior research suggests that a more detailed examination is needed of the dynamic relationship between the different actors in a quadruple helix model, a case
study method was selected. As Miller et al. (2016) state, more case-based research at micro levels is needed to fully understand the complexity of activities that take place in a quadruple helix setting. A case study has the potential to generate new insights that can refine and further develop current theoretical knowledge (Eisenhardt and Graebner 2007; Siggelkow 2007). One drawback, however, is that a single case study does not provide us with the ability to generalize. Nevertheless, a single case study, well-grounded in previous literature, can help us to make conceptual and theoretical contributions that go beyond the specific case (Siggelkow 2007).

We have studied Robotdalen, a smart specialization initiative in Sweden that is working from a quadruple helix perspective (Höglund and Linton 2018). The selection of this case could be described in terms of an atypical or extreme case, as our objective has been to achieve the greatest possible amount of information about a given problem or phenomenon. As Flyvbjerg (2006, 229) argues, atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation studied. In other words, we selected the case of Robotdalen as it could give us further information and enhance our understanding of how a quadruple helix initiative can collaborate with different actors. Robotdalen also fits the description as a hybrid autonomous organization that was designed with the goal to integrate all triple helix spheres in an attempt to promote innovation (Champenois and Etzkowitz 2017). Thus, Robotdalen is a collaboration between multiple organizations, including universities, global enterprises, SMEs, municipalities as well as regional and local government. In this paper, we also discuss the fourth helix, that is, users and civil society in terms of firms of different sizes as well as hospitals, municipalities and seniors in Sweden that in different ways benefit from healthcare robot innovations provided by Robotdalen in collaboration with the other helices. Robotdalen is financed by the Swedish Governmental Agency for Innovation Systems (VINNOVA), the EU Regional Development Fund, municipalities, counties, and industry representatives, among others. The overall aim of Robotdalen is to ‘enable commercial success of new robot innovations, focusing on technical solutions for industry, service, and healthcare’ (robotdalen.se).

3.2. Data collection

We take a case study approach that focuses on the interpretative aspects of the case (Stake 1995). As a result, we have utilized a qualitative research method to theorize and conceptualize an understanding of the relationships (activities, resources, and actors) of Robotdalen and address gaps in existing theory (cf. Siggelkow 2007) from a quadruple helix perspective. The empirical material has been collected between 2009 and 2017 through yearly interviews with members of the senior management team as well as the general manager and vice-general manager of Robotdalen. Over the years, we also met with the various board members on a number of occasions and with numerous financing bodies. Fifty-seven interviews in total were conducted with the Robotdalen management team, Robotdalen employees, board members, financing bodies, regional representatives, politicians, public officials, university representatives, and industry representatives (Table 1). The interviews lasted approximately 60–90 minutes and were
recorded and transcribed verbatim. In addition, the interviews were complemented with documents such as PowerPoint presentations, agendas for meetings, websites, and press releases. Even if we were not able to directly interview the users in all cases (e.g. elderly people), we still have been able to gather much information, for example, during the interviews with the elected representatives from the cities, as it became clear that they were concerned about the benefits directly to the people of their cities: for example, how their community could directly benefit from the robotics solutions.

3.3. Analytical process

The coding process can be described as the precursor of the analysis, and a common way to code is to work with different categories. The prime focus of the coding stage is not to find results but to manage a large amount of text. Based on the theoretical framework of the quadruple helix as a network of relationships with a focus on actors, resources, and activities, we started to categorize the empirical material in line with the three helices of government, industry, and academia (cf. Miles and Huberman 1994). Through extensive readings of transcriptions and documents, we got a first picture of what activities and resources were in use among the actors.

In a second step, we started to analyze the content of the categories in search of patterns among and between the different actors, as well as in the activities performed and resources used (cf. Miles and Huberman 1994). Similar to Miller et al. (2016), for the analytical process, we iterated between the empirical data and the literature. As we take on a theoretical framework of the quadruple helix as a network of relationships, we have tried to understand the activities taken by the triple helix actors in relation to the fourth helix of society and the user. We believe that this continuously iterative process throughout the research assisted us to gain refined and evolved theoretical knowledge (Eisenhardt 1989). The findings from this analysis are presented in the result chapter.

3.4. The case of Robotdalen

The quadruple helix framework places a stronger focus on cooperation in innovation within and across regional innovation systems (Carayannis and Campbell 2009, 2012) that could serve as the foundation for diverse smart specialization strategies (Carayannis et al. 2018). The smart specialization strategy adopted by the EU is often referred to as the research and innovation strategy for smart specialization (RIS3). In this paper, we study a RIS3 initiative of Robotdalen (Högland and Linton 2018), a non-profit organization that has been acknowledged for its excellent performance in the RIS of Mälardalen in Sweden (Cooke et al. 2010). Robotdalen started formally
as a project in accordance with the triple helix framework in 2003, where two regional universities (Mälardalen University and Örebro University), a number of global enterprises (e.g. ABB, Volvo CE, Atlas Copco and ESAB), a greater number of SMEs, several municipalities, regional and local governments as well as hospitals engaged in collaboration. Robotdalen is situated in a Swedish region called Mälardalen, which covers three counties and several municipalities, and is hosted by one of the regional universities, Mälardalen University. Moreover, Robotdalen is based on the smart specialization policy initiative from the Swedish public authority of Vinnova called VINNVÄXT (Regional Growth through Dynamic Innovation Systems). The policy initiative of VINNVÄXT started in 2003 to focus on areas in decline and where regional industrial transformation was taking place (Nuur, Gustavsson, and Laestadius 2009). The goal of the VINNVÄXT initiatives is to recognize and target regions which can strongly benefit from a smart specialization program and become world leading in this specialization. Vinnväxt funds programs up to about 1 million euros a year for about a 10-year period, and financing is also required from local and regional governments as well as firms established in the area. The European Regional Development Fund has also funded Robotdalen, as it is seen in line with the smart specialization strategy of the European Union. Robotdalen has also been part of several European Union programs, for example, euRobotics and SPARC, which have been resources for international networking for both Robotdalen as an organization and the startups within Robotdalen. These EU programs have helped Robotdalen to become more internationalized in terms of collaboration networks and commercialization efforts.

Hence, Robotdalen is expected to be a world leader in robot-based automation with a focus on three different areas: (1) mobile robots providing service, (2) innovative automation for industry, and (3) technology for independent life. These three areas have been identified because they are expected to have an excellent future and since competence in these areas already exists in the region. Mobile robots providing service can be, for example, autonomous loading and mining equipment which is represented by two global firms in the region, Volvo Construction equipment in Eskilstuna and Atlas Copco in Örebro. Innovative automation for industry is a mature area with a long tradition in the region and consists of automation robots for industry; in Robotdalen, this area is represented by the global firm ABB. Technology for independent life includes different types of robots in the health care and care of the elderly, for example. This is a relatively new field of robotics and is expected to have tremendous growth in the near future. No large global firm in the region existed when Robotdalen was launched. However, Robotdalen has been able to attract firms to move to Robotdalen. For example, Giraff Technologies, with their telepresence solution Giraff, moved their firm from the Silicon Valley to Sweden to become a member of Robotdalen.

The Robotdalen initiative aims to develop and strengthen the existing technological knowledge and to create an efficient structure where new products can be taken to market and new firms have the ability to develop. Creating and strengthen academic research centers is also the ambition. In fact, Robotdalen has developed 45 new products and created 28 new firms before the end of 2017.
4. Results

In the next part of the paper, we will present the results from analyzing Robotdalen from our theoretical framework of the quadruple helix as a network of relationships. Table 2 gives an overview of relationships between Robotdalen and a few examples of actors from the different helices. The table also shows the value of the relationship for Robotdalen as well as the specific actor.

4.1. Government

Robotdalen works with several different government organizations. On the national level, Robotdalen collaborates with Vinnova, the state agency for innovation. Robotdalen is founded on the basis of substantial financing from Vinnova as a Vinnvåxt initiative. Therefore, Vinnova has been a central partner for Robotdalen, as a large financier but also in the form of knowledge exchange between different Vinnvåxt initiatives and other related activities. As the main financier of Robotdalen, Vinnova supported Robotdalen in order to enhance the innovation capacity through new firms and products within the field of robotics. A representative from the government positioned Vinnova as a customer and stated the following:

Vinnova is the biggest customer. The other [financiers] adapt to Vinnova’s goals and they [Robotdalen] deliver towards it […] which is wise for otherwise they have no funding. Vinnova and the other financiers are pleased because they have been included in the strategic goals [of Robotdalen].

On a regional level, Robotdalen works with the regional governments of Örebro, Västmanland, and Sörmland. The regional governments mainly contribute with financial support and attend the yearly conference of Robotdalen to see the previous year’s results and also to discuss the activities and plan forward. For the regional actors, Robotdalen can assist with creating regional growth and innovation. One regional representative stated:

The region invested money when it saw that the other regions also did the same; you saw that there was a point in helping build this up.

On the local-level government, there are three cities involved in Robotdalen: Eskilstuna, Örebro, and Västerås. The activities and resources are very similar to the regional government, and they provide financial resources and attend the yearly conference. On the local level, robotics is also seen as something that will benefit the citizens of the cities with applied solutions, for example, elder care. The local governments see that they support and make the local industry more competitive and also develop it through robotics and that it is important to build up knowledge centers around academia. One head of the municipal executive board said:

Our engagement is partly an economic addition to Robotdalen. I also think that we can say that our science park creates larger possibilities for Robotdalen’s expansion and to get more strength here.

This statement indicates the financial support to Robotdalen, but also that Robotdalen gets support and collaborates with the local innovation system, in this
Table 2. Examples of relationships between Robotdalen and different actors, resources, and activities.

<table>
<thead>
<tr>
<th>Relationship with RD</th>
<th>Actor, Resources, &amp; Activities</th>
<th>Robotdalen</th>
<th>Actor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government National</td>
<td>Actor: Vinnova Resources: Financing Activities: ERFA, coaching, yearly conference</td>
<td>Receive financial resources, Receive feedback and ideas</td>
<td>Achieve national innovation Goals</td>
</tr>
<tr>
<td></td>
<td>Resources: Financing</td>
<td>Receive financial resources</td>
<td>Achieve national growth</td>
</tr>
<tr>
<td></td>
<td>Activities: Yearly conference</td>
<td>Receive feedback and ideas</td>
<td>Achieve regional innovation goals</td>
</tr>
<tr>
<td>Regional Länsstyrelsen Väst man land</td>
<td>Actor: Vinnova Resources: Financing Activities: Yearly conference</td>
<td>Receive financial resources</td>
<td>Regional growth</td>
</tr>
<tr>
<td></td>
<td>Resources</td>
<td>Receive feedback and ideas</td>
<td>Local growth</td>
</tr>
<tr>
<td></td>
<td>Activities: Yearly conference</td>
<td>Receive feedback and ideas</td>
<td>New jobs</td>
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<td></td>
<td>Receive feedback and ideas</td>
<td>Showroom</td>
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<td>Receive feedback and ideas</td>
<td>Information from customers</td>
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<td>Receive feedback and ideas</td>
<td>Innovative environment</td>
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<td>Receive feedback and ideas</td>
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<td></td>
<td>Receive feedback and ideas</td>
<td>Research collaborations and network with academia</td>
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<td>Receive feedback and ideas</td>
<td>Development of new robot that assists firefighters</td>
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<td></td>
<td>Receive feedback and ideas</td>
<td>Increase the number of robotics firms</td>
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<td></td>
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<td>Receive feedback and ideas</td>
<td>Show the usefulness of robotics</td>
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<td>Receive feedback and ideas</td>
<td>Increased the amount of robotic activities</td>
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<td></td>
<td>Receive feedback and ideas</td>
<td>Collaborations with academia and SMEs</td>
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<tr>
<td></td>
<td></td>
<td>Receive feedback and ideas</td>
<td>Increased quality of education through real-world cases</td>
</tr>
<tr>
<td>Industry Large firms</td>
<td>Actor: ABB Resources: Employees &amp; Robots Activities: Customer interaction</td>
<td>Development of new robot that assists firefighters</td>
<td>Financing</td>
</tr>
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<td></td>
<td>Resources: Financing Activities: Yearly conference</td>
<td>Increase the number of robotics firms</td>
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<tr>
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<td>Activities: Customer interaction</td>
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<td>Increased the amount of robotic activities</td>
<td>Increased quality of education through real-world cases</td>
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<td>Collaborations with academia and SMEs</td>
<td>Produce pre-studies that can lead to larger research funding</td>
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<tr>
<td>Small firms FUMO</td>
<td>Actor: FUMO Resources: New robot Activities: Coaching</td>
<td>Development of new robot that assists firefighters</td>
<td>Financing</td>
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<td></td>
<td>Resources: New robot</td>
<td>Increase the number of robotics firms</td>
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<td>Activities: Coaching</td>
<td>Show the usefulness of robotics</td>
<td>Network and contacts</td>
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<td>Increased the amount of robotic activities</td>
<td>Increased quality of education through real-world cases</td>
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<td>Collaborations with academia and SMEs</td>
<td>Produce pre-studies that can lead to larger research funding</td>
</tr>
<tr>
<td>Academia Education Örebro University</td>
<td>Actor: Örebro University Resources: Students &amp; Teachers Activities: Create robot-based solutions and financial calculations of implementation for SMEs</td>
<td>Development of new robot that assists firefighters</td>
<td>Financing</td>
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<td></td>
<td>Resources: Students &amp; Teachers Activities: Create robot-based solutions and financial calculations of implementation for SMEs</td>
<td>Increase the number of robotics firms</td>
<td>Business development coaching</td>
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<td>Activities: Create robot-based solutions and financial calculations of implementation for SMEs</td>
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<tr>
<td>Commercialization Retenua</td>
<td>Actor: Retenua Resources: New robotics product Activities: Coaching</td>
<td>Development of new robot that assists firefighters</td>
<td>Financing</td>
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<td></td>
<td>Resources: New robotics product</td>
<td>Create new robotics based firms</td>
<td>Business development coaching</td>
</tr>
<tr>
<td></td>
<td>Activities: Coaching</td>
<td>Collaboration with academia</td>
<td>Produce pre-studies that can lead to larger research funding</td>
</tr>
<tr>
<td>Research Örebro University</td>
<td>Actor: Örebro University Resources: Researchers &amp; Labs Activities: conduct pre-studies for Robotdalen</td>
<td>Get help with projects where research knowledge is important</td>
<td>Produce pre-studies that can lead to larger research funding</td>
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case, a local science park. A different regional government representative stated that the activities and resources put in by Robotdalen have created value for the three regional counties as they have started to collaborate in a better way:

Robotdalen proves to be a good concept because we can better agree within our three regions now and share stuff.

Yet, another regional representative from the government stated that Robotdalen create value for the three regions as they contribute to regional growth by creating new firms and products:

Robotdalen contributes to growth in the three regional counties, definitely. When you create products and new firms, jobs are also created.

Several of the new products and firms are launched within the health care sector, where Robotdalen plays an important role as a collaboration platform for public and private actors to meet in different constellations. A government representative, for example, stated that a collaboration between the three regional county councils and the hospitals, through Robotdalen, gives industry a unique opportunity to test the products before they are taken into use:

Health care should be a growth area that also includes county councils. There are not so many private actors, county councils and politics belong together […] you have several hospitals and county councils that you can try, and you have three county councils [within the Robotdalen collaboration] that you can have as a test bed.

4.2. Industry

It is important for Robotdalen to work closely with many different firms in industry. Robotdalen has many collaborations with many firms on different levels. Several of the larger firms in the area collaborate with Robotdalen; these include robotics company ABB in Västerås, mining equipment company Atlas Copco in Örebro and Volvo Construction Equipment in Eskilstuna. They all express that they value the work of Robotdalen as they are enabling their organizations to develop new products and assist them in possible renewal processes. A representative from ABB stated that an investment of resources in Robotdalen was made as they saw an opportunity that Robotdalen could generate value in return, as they could:

Create not only growth more generally within the robotic market but specifically where our [ABB] products could come to use.

Also, several industry respondents described that Robotdalen was seen as an entrepreneurial organization that gets projects completed, and another ABB representative stated:

Usually, if we are doing radical innovation activities, it is always a balance between the short and long-term output, but in collaboration with Robotdalen and the initiatives that were set up, people got time and an opportunity to focus on the long term. In this way, Robotdalen has been invaluable to us.

Moreover, several representatives from industry stated that they collaborate with Robotdalen with more risky projects where the future market is uncertain. These
projects might not have been allowed to continue within the existing organizations, but Robotdalen has the ability to find funding and competence to continue with these highly uncertain projects.

Robotdalen has also actively worked to engage more actors, to show that they are a central and important actor as well as to be able to secure more funding from the different actors. One example of bringing in new partners is with a large construction company (Skanska) that needed automation for building bridges. Because there was not a ready-made solution or any solution that could be easily modified to solve the problem, the project was more suited for Robotdalen. Moreover, Skanska wanted ABB to create a solution for them, but since there were no ready-made solutions and the solution would require significant R&D, it was decided that Robotdalen would be better suited to handle the project, although ABB is definitely still involved in the project. Robotdalen is therefore seen as a good partner to test a proof-of-concept, and therefore Skanska has ordered the project from Robotdalen. The project needs input from Robotdalen’s in-house robotics experts, their test centers, student’s projects, and ABB. A project manager from Robotdalen states:

There are many uncertainties and new functions that need to be in action; therefore, Robotdalen is more suited for this.

In a different project, ABB decided to start a collaborative robotic test center together with Robotdalen with the help of financing from the Swedish state agency Vinnova. ABB decided to locate the center at Robotdalen because it is a good environment for such a center due to its openness. A manager from ABB declares:

What we want to achieve with the center is, in line with Robotdalen’s general stipulation, to have a meeting place for customers, that is, the industry.

At the test center, ABB can take on projects that are more complicated, and that takes a lot of time initially since at ABB it is difficult to accommodate these types of projects as they do not fit in with the day-to-day operations.

The large firms are a big part of the activities in Robotdalen, but there is also a substantial number of new firms and small firms that collaborates with Robotdalen. Many new firms have been created with the help of Robotdalen. For example, the firm YourFlow develops software to visualize and quantify the value stream for production firms. This software helps firms to map their flows and produces basic data that can be used for the decision to invest in robotics, and thus be able to show how robotics can be incorporated in the production process. Robotdalen was involved in YourFlow before it was incorporated and helped early on with a beta version of the software. A representative from YourFlow states:

…on the other hand, the support, the business coaching has been much more worthwhile for us; it has been very important for some things. This first sounds small, but it was a lot of support for us. In order to make certain decisions… But the other type of support is with contacts which is important to us. Because that’s where we have our biggest weakness, it’s development of market and selling because there we have been stuck in some things.

Another example of a newly started firm that Robotdalen has been a collaboration platform for is Robotics Care, which was acting in the market niche of the health
sector by introducing a robotic shower solution for elderly and disabled people who wanted to take showers independently. The product is now tested and evaluated by several municipalities, and not only in the regions of Robotdalen. A last example of a product also within the health care sector is the robot Bestic, which is a robot that helps people eat independently instead of being fed by another person. The robot Bestic is also tested and evaluated within different municipalities outside the regions of Robotdalen.

4.3. Academia

The management of Robotdalen has focused a lot of their resources on creating a platform for academia and SMEs to collaborate. One way of doing this was to give the students an opportunity to gain practical, hands-on experience by conducting pre-studies with different SMEs where they explored their possibilities to further develop their operations with robotics by suggestions on how the SMEs could improve their efficiencies with robotics. In other words, the students were helping the SMEs to become aware of the possibilities with robotics. In this way, Robotdalen enabled value not only for the students that could apply their acquired knowledge from academia on real cases, and the SMEs that got help on moving their business forward, but ABB also got an opportunity to sell the needed robotic solutions to the SMEs. A university representative stated the following:

\[\text{It really benefits us if we get good teaching from the collaboration, it stimulates the students and develops them, and that’s great for us. [...] Companies like ABB, they have a financial value also for them [...] So it’s no wonder if they put in some [resources] too. Especially if it’s not hard-core money, but more in kind-contributions like spending hours or something like that.}\]

Robotdalen has also focused on being a collaboration platform for the partner universities to conduct research about robotics and automatization in cooperation with industry. As a result, they have sponsored some research projects with financial resources, as well as supported several pre-studies in collaboration with Robotdalen that have led to the financing of large research projects with different actors from industry such as Volvo, ABB, and Atlas Copco. Another university representative stated:

\[\text{Atlas Copco has very clear interests in the development here at universities with self-governing devices [automated robots] that enter and drill into mines. There are obviously bilateral interests.}\]

There are also, however, some disappointments expressed from academia, as a representative stated that the collaboration between Robotdalen and the university was unclear, and the value of the collaboration is questioned:

\[\text{In the collaboration with Robotdalen, the role of the university is very diffuse, and I do not know what we gain from it.}\]

In addition to education and research, Robotdalen has also taken a third role in terms of commercialization of ideas from the universities. Both students and researchers can get support from Robotdalen with the commercialization of robotics-related ideas. For example, Retenua is a research-based firm that has developed a
system called RefleX. It is an embedded vision system for the detection of human workers from heavy mobile machinery operating at industrial worksites. A representative from Retenua stated:

We had contact with Robotdalen relatively early and had some discussions with [them]. And we also got some money from the Robotdalen, but there were also some meetings where we went through strategy and how to take the next steps and what to do and so on.

Lastly, we have FUMO, a newly started firm that collaborates with Robotdalen. The firm develops a robot to assist firefighters in different dangerous situations. FUMO use many master’s level students in the development of the robot. The respondent indicated that it got in contact with the university the first time through Robotdalen, and thereafter the collaboration with the university has continued with both classes using FUMO as a case study and thesis students working directly on the robot. The firm has been collaborating with Robotdalen since it started and has progressed over several years, and indicates the importance of the funding received from Robotdalen:

[The amount has not been large] but it has been very valuable means, because they have been able to enter and bridge other financing [at critical times].

The quotation implies that the amount of funding is not that big, but that the timing has been critical when FUMO has been in-between larger financing from different financing bodies.

5. Discussion

The results from the analysis show that there are many different types of input in terms of resources and activities, within and between the helices, as well as many different types of valuable outputs for the different actors in the helices.

From a governmental perspective, it is shown that the government provides funding from many different levels of government (local, regional, and national). This involvement of different governments seems to create value by providing innovative output in the form of new products and firms which create jobs. Robotdalen can be seen as a unique regional context (Rodríguez-Gulías, Fernández-López, and Rodeiro-Pazos 2018) by focusing on robotics, which seems to be valued by the governments. Robotdalen is active in the region by collaborating with the local innovation system with, for example, science parks. In addition, it is interesting to note that Robotdalen also facilitates collaborations that usually do not take place between government units, for example, between the different regions. In line with Nordberg (2015), we argue that if peripheral regions get connected, they most likely increase their ability to stay competitive and to have an important role to play in larger innovation networks. Moreover, ‘soft infrastructure’ for the helix models such as networking and collaboration over geographical borders that do not usually collaborate can have a positive impact on a RIS (cf. Colapinto and Porlezza 2012). This includes the government increasing collaboration between counties, but also connecting the innovation support system of, for example, incubators and science parks across geographic borders (Höglund and Linton 2018).

Both large and established firms, as well as small and new firms, collaborate with Robotdalen. The larger firms highlight that Robotdalen is an entrepreneurial
organization suited well for projects that do not fit in the day-to-day operations within the firms. Robotdalen is also recognized for creating a marketplace for robotics. Moreover, the firms in our study report that customers and suppliers are important sources of information (cf. Doloreux and Dionne 2008). Hence, Robotdalen and its extensive network help the firms to find new relationships that can lead to potential collaboration and knowledge transfers (cf. McAdam et al. 2012). The larger firms also highlighted that initiatives like Robotdalen are highly needed as they can act as a cooperation platform not only for the triple helix actors in the region (cf. Lee, Olson, and Trimi 2012) but also the fourth helix. Interestingly and somewhat surprising, our results show that for the startups and small firms, it has at times been critical that Robotdalen has been able to quickly contribute with small, but critical funding that has helped the firms to keep afloat. Accordingly, financiers can have a large impact in a quadruple helix setting (cf. Colapinto and Porlezza 2012; Höglund and Linton 2018). It is not, however, always the large amounts of funding that are the most important ones. Also, in line with previous research on startups (e.g. Hasche and Linton 2018), startups can benefit from learning processes through networks and relationships. Startups engaged in Robotdalen underline the importance of business development coaching and having access to a solid network of relationships to assist in the commercialization process.

Engaging academia in quadruple helix collaborations has been seen as a complex task, where academia has long valued publications and research grants over collaborating with quadruple helix stakeholders (McAdam, Miller, and McAdam 2018). Nonetheless, Robotdalen has been a collaboration platform for academia in several ways. For example, Robotdalen has been important for the research centers at the two universities, in line with previous research that acknowledges the importance of a triple helix organization to facilitate collaborations and possibilities for joint research projects between firms and academia (Ryan, Geoghegan, and Hilliard 2018). Research centers have been found to be able to achieve higher results when collaborating closely with industry (Aguiar-Díaz et al. 2016) and can depend on how central the research center is in the network (Chen et al. 2017). Robotdalen has also been a platform for students and industry to meet. As a result, important practical experiences for students have been created in the form of courses where Robotdalen can provide real business cases, and Robotdalen has also been a source of projects for thesis students to work on. In addition to research and education at the universities, Robotdalen also assists the universities with the commercialization process of robotics, a complex task in a university setting (McAdam, Miller, and McAdam 2018). Moreover, by addressing the activities of Robotdalen from a quadruple helix perspective, we have shown how the actions of the different helices challenge traditional university incubation models by recognizing value-adding activities of the actors, resources and activities in the quadruple helix (cf. McAdam, Miller, and McAdam 2016).

As previously discussed, Robotdalen started as a triple helix initiative with the aim of becoming an arena in which actors from government, industry, and academia could collaborate around innovative robot-based automation. Over time, as Robotdalen has developed, the innovative collaborations, between and within the
three helices of government, industry and academia, have extended to include actors from the fourth helix. In previous research, the fourth helix has been discussed and defined in a variety of ways, where no consensus seems to exist in terms of definitions and ways to operationalize the additional helix (Carayannis and Rakhmatullin 2014; Höglund and Linton 2018). In accordance with Ivanova (2014), our results show that actors between and within one of the triple helices, that is, government, industry, and academia, often act as users in one way or another over time.

One case discussed within the paper is the large construction company Skanska, which was looking for a more efficient solution to building bridges. Skanska got in contact with ABB, a large firm that is affiliated with Robotdalen, to find a solution to their problem. Since there was not a ready-made solution or any solution that could be easily modified to solve the problem, ABB suggested that the project was more suited as a collaboration project for Robotdalen. Thus, initially, Skanska became a user involved in the innovation process in developing the solution together with Robotdalen. Later, the relationship developed from user involvement in innovation processes to becoming an affiliated partner. Accordingly, the roles of the different actors within a quadruple helix initiative can vary over time, where users can be found in all of the three helices of government, industry, and academia. Users can have multiple roles in the collaborations as well as belonging in any of the helices.

In line with Carayannis and Campbell (2014), we argue that the fourth helix is human-centered and that innovation systems should serve the civil society and the citizens. Our results have discussed how the small firm of Robotics Care, acting within the health sector, saw an opportunity to provide a new product for elderly and disabled people who wanted to take showers independently. The robotic shower solution was developed with the help of Robotdalen and is now used and being evaluated by several municipalities, including Eskilstuna and Västerås, but also other municipalities not related to Robotdalen (e.g. Uppsala and Karlstad). Another similar example is the case of the robot Bestic. As described previously, the robot is a product that helps people to eat independently instead of being fed by another person to increase their independence when eating. The robotic solution is being used in many different municipalities including the municipality of Värnamo.

In the examples discussed, innovative products are developed by small firms in collaboration with Robotdalen and then incorporated and used as products within the sector of elderly care in different Swedish municipalities. In the two cases discussed, we can find other types of users than discussed previously in the paper. The municipalities that decided to try out and use both the robotic shower solution and Bestic are one type of user, that is, a user that places an order on an offering, pays for the solution and uses the solution in its operations. Magnusson (2003), as well as Ståhlbröst (2008), argue that such a user should be called a customer; that is, a customer is a person who is paying for the product, not necessarily meaning that the product will be used by that person. Besides the customer in the discussed cases, we can find yet another type of user, and that is the end user (cf. Ives and Olson 1984). The concept of the end user includes the users who actually use the output of the value-creating process in some way where the output is developed for a specific and identifiable group of users (Ives and Olson 1984).
Both the shower robotic solution and Bestic include value for end users in terms of elderly and disabled people in society who are directly benefiting from solutions developed within Robotdalen. Accordingly, users in the quadruple helix framework can be defined in several ways depending on the context. Thus, users can be businesses, organizations, citizens, society and many more things. As a result, in studying the quadruple helix which includes the user, end user and society it becomes difficult to define the user, end user and society, especially as an actor; for example, the government can take on all of the above roles depending on the context.

6. Conclusion

Over the years there has been important work made regarding RIS with a quadruple helix framework within a European context (see, e.g. Arnkil et al. 2010; Betz et al. 2016; Carayannis and Campbell 2006; Carayannis, Grigoroudis, and Goletsis 2016; Cavallini et al. 2016; Lew, Khan, and Cozzio 2016; Lindberg, Danilda, and Torstensson 2012; MacGregor, Marques-Gou, and Simon-Villar 2010; Kolehmainen et al. 2016). In this paper, we specifically studied an output of the smart specialization strategy (RIS3) adopted by the EU. By doing this, we have met up with recent calls to research the quadruple helix from a micro perspective and, more specifically, the dynamic relationships, synergies, collaborations, coordinated environments, and value creation activities (Cunningham, Menter, and O’Kane 2018; Edquist 2011; Höglund and Linton 2018; McAdam and Debackere 2018; McAdam et al. 2012). Through a single case study, we have contributed with a more fine-grained analysis of the relationships and the value created through them. We have, in line with Kriz, Bankins, and Molloy (2018), contributed with an enhanced knowledge of the complexity and the relationships in terms of actors, resources and activities in the quadruple helix setting, in this way adding to our knowledge of how the relationships of actors, resources and activities as a context generate conditions for value creation. In addition, and also similarly to Cavallini et al. (2016), our study highlights the importance of interaction between spheres to be an advanced innovation setting, but nonetheless, the study also indicates the complexity of achieving interaction between the spheres.

In a quadruple helix setting, it is important to notice that there is a lack of consensus in previous research on how to define and operationalize the fourth helix (Ivanova 2014; Nordberg 2015), but there is a tendency to either take a civil society approach or an end-user approach. Our studied case shows that collaborations between industry, academia, and government also strive to include users and end users while simultaneously improving the civil society. Based on these results we argue, in line with Höglund and Linton (2018), that the fourth helix is far more complex to limit it to simply become a fourth separate helix of users and end users, a conclusion also supported by previous work of Ivanova (2014) and Nordberg (2015). In light of this, we conclude that we also need to address the fourth helix as a whole (an arena) where societal value creation is generated by the dynamic relationships (activities, resources, and actors) between academia, industry, and government.

Similar to the findings of Nordberg (2015), our case illustrates how the coevolution of the political and knowledge transfer alters the fourth helix and opens up the triple
helix actors toward each other. Thus, Robotdalen as a collaboration platform within the RIS have generated several new products and firms, connected several stakeholders from industry and academia, and placed the government as a central actor in the commercialization process, in this way providing more value-adding activities to society in a quadruple helix perspective.

In this paper, we focused on the relationships in terms of actors, resources and activities in the quadruple helix setting. However, our results of studying a RIS3 initiative indicate that to further enhance our understanding of the micro-dynamic relationships in a RIS from a quadruple helix perspective it becomes important to also study the knowledge production of the actors, their activities and use of resources. This could preferably be made from a Mode 3 knowledge production system, as it is an important part of the quadruple helix framework (see, e.g. Carayannis and Campbell 2009, 2011, 2012; Carayannis et al. 2018b). In this way, we could learn more about how each helix is passing knowledge in the relationships respectively focused upon, for example, funding, science, and technology (c.f. Betz et al. 2016).

To sum up, the avenues for future research are many, and we believe that the quadruple helix literature would benefit from more empirical studies, for example, more micro-level qualitative studies to understand the fine-grained dynamics (e.g. Höglund and Linton 2018), as well as studies of a more quantitative nature that can measure and generalize results from a larger sample population (Linton 2018). Future quadruple helix research may also investigate how relationships evolve and how actors’ roles change over time, as well as the entry and exits of actors within quadruple helix networks. Moreover, it would be fruitful to get a deeper understanding of how products are developed, on a micro level, and the importance of quadruple helix relationships in this process.

Note
1. If we translate the Swedish word Robotdalen, it means the Robot Valley.

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