

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

Working paper

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Abstract. The Reformers project aims to develop a sustainable ecosystem with the quadruple helix approach. This approach, evolved from the triple helix theory of knowledge exchange for innovation, adds a fourth element: the social factor. The question is whether this concept can be easily applied to smaller regions without universities for fundamental research and leading innovative industries. Although the quadruple helix adds the social factor, the literature seems to be more inspired by new information and communication technology than by sociological knowledge. This paper starts with the social systems theory of Parsons (AGIL scheme), a tool used to develop a region in a structured manner in line with the basic principles of one of the founders of the triple helix Leydesdorff. However, this paper takes then different line than Leydesdorff from his scientometric operationalization inspired by Luhmann to the philosophy of sociologist Habermas with the lifeworld and system approach. Innovation is learning, which is why there is a brief paragraph to learning what is useful in that context. Learning in a region requires proximity to the right knowledge institutions and companies in that region. This can only be achieved with the internet. To model this, an attempt is made to further elaborate these issues using dynamic systems and Parsons' diagram.

Introduction

The Reformers project aims to develop sustainable ecosystems through the quadruple helix approach in the Renewable Energy Region a Flagship of the region Alkmaar. This approach, which evolved from the triple helix theory of knowledge exchange for innovation, adds a fourth element: the social factor. However, the question is whether this concept can be easily applied to smaller regions without universities and leading innovative industries, such as in Eindhoven. In the context of path dependency, the development of a region should be in line with activities that have arisen in the past. Information systems also determine the scenarios for paths in the future, but it is people who, through learning, have to make that happen.

This paper begins with the social systems theory of Parsons (AGIL scheme), a tool to develop a problem in a structured manner. This can be further elaborated with empirical research in subsequent papers. A system is a collection of objects selected by the observer, where the relation is the causal connection providing coherence between

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

objects. Structure is the total pattern, or the collection of relations of an object set as defined by the observer, where the system boundary is the line drawn by the observer between an object set of the system and the environment. An aspect system is a subset of the relations in the total system in which all elements remain unchanged, while a process is a system or subsystem that changes over time, which can be in the objects or the relations.

It is important that these aspects are determined by the researcher's experience and life world, where new media are prominent in mainstream society. This paper takes a different perspective, based on the philosophy of Kant, the sociology of Parsons, Luhmann and Habermas. This paper discusses how learning takes place in a region, indicating that this can also be analyzed at different levels using the scheme of Parsons.

This paper contains 6 paragraphs.

1. *Social system theory*

This paper takes sociological systems theory by describing Parsons' AGIL scheme. This scheme can be built up from psychology to even the human condition (like Russian matryoshka dolls) but is limited here to the social system, which can also include, for example, how success factors of companies can be created by a country or region. (Hofman, Foks, & Kokhuis, 2000).

2. *The triple helix of Leydesdorff* (Leydesdorff, 2020)

One of the founders of the triple helix Leydesdorff also starts with philosophy and sociology but focuses mainly on communication theory with scientometric, the quantitative aspects of scholarly literature as operationalization. This has limitations certainly for regions like Alkmaar without a university with many scientific papers. This can be corrected by inserting the AGIL scheme. (Hofman & Burgmans, 2005).

3. *The Habermas versus Luhmann discussion*,

For that one of Leydesdorff's key points is his choice of Luhmann over Habermas who pays attention for the lifeworld which in Habermas' view is colonized by the system. The question whether people are controlled by systems is increasingly relevant with new (information) technology.

4. *Innovation and learning*

Innovation, what the quadruple helix is about is learning. It is then important at what level one wants to learn in a region, what environment is needed and where there are limitations. Information and communication systems can be supportive in that, but it is the people in the region who have to absorb it (B. Nooteboom, 2008) (Hofman & Leeuwen, 1998) (Hofman & Huijsmans, 1995).

5. *Network oriented modelling for adoptive networks*

Leydesdorff used three levels of communication but takes distance from neuroscience and big data. That seems partly unjustified. By analogy and better naming relationships in terms of spheres of influence, patterns can be analyzed. For this reason, network-oriented modelling for adoptive networks is introduced, where Leydesdorff's levels fit in the AGIL scheme. (Hofman & Treur, 2021).

6. *The Quadruple Helix*

Finally, an article that analyses the current trend around the quadruple helix is briefly described to illustrate the difference with the quadruple helix approach

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

described here for small regions without a university for fundamental research and global industries.

A summary and conclusion with key issues for further research conclude the paper.

1. The sociological AGIL reference scheme

This section first explains the AGIL scheme of Parsons. The sociologist (and economist) Parsons developed a reference scheme (Parsons, Bales, & Shils, 1953), applied it in practice (Parsons & Platt, 1973) and tried to elaborate it using systems theory (Adriaansens, 1976); see **fig. 1**. In his scheme Parsons used insights from biology and economics (Moss & Sauchenko, 2006); (Turner, 1999). However, systems theory was not yet developed well, and sociologists are not always attracted to mathematical models. So, this by itself useful reference scheme (Kerkhoff, 2007); (Jong de, 1997) was somewhat forgotten and the theory called an important 'high way out of order' (Castellani & Hafferty, 2009). Later, computer technology and modeling made great progress, e.g., (Kauffman, 2000). Economic science (Moss & Sauchenko, 2006) made the best use of this and became dominant over the fragmented sociological science of which it in fact forms a subdomain.

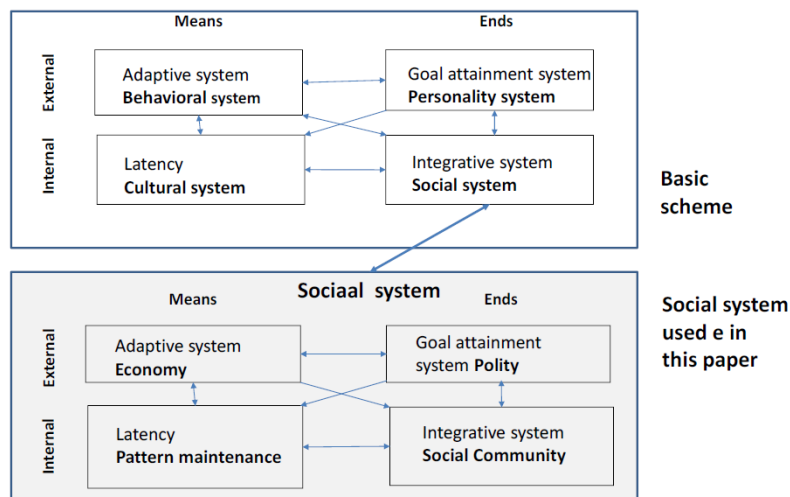


Fig. 1. Parsons reference scheme

The AGIL scheme, as it is called, is a reference scheme within which environmental influences and social changes can be interpreted. It is not a full blueprint, but it at least provides recognizable anchors. A system usually tends to reach an equilibrium, but over time it will adapt to changes in the environment to survive. It always differentiates into several processes or subsystems, each with its own function (Parsons & Platt, 1973)

Basic elements are:

- **Adaptation** that is constantly needed in interaction with the environment because resources are needed from the environment to survive.
- **Goal attainment** establishes priorities that are good for the subsystem.
- **Integration** promotes solidarity in the social system.

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

- **Latency** or pattern maintenance is necessary to maintain the underlying values of variables. This stems from history or evolution (Parsons & Toby, 1977) with learning and education as an important factor in the social system.

This is the top part of **fig. 1** and the basic scheme filled in with the individual part that carries the social subsystem system within it. A clear distinction is made in function of the subsystems, such for as for example means for the subsystem on the top left and ends on the top right. This can be completed at a different level for the social system:

- The economic system (A), which allows the system and *adapts* to what the environment offers to survive as a subsystem.
- The politicians for goals and *government* (G) that sometimes-subordinate individual needs for the benefit of the whole and uses power for the community.
- The community (I) is the *integration* of other subsystems based on norms and customs.
- The *latency* (L) or pattern maintenance system for the social system, also called the fiduciary system, is necessary to maintain underlying values. This goes through the family, education, but also knowledge development is part of it (universities, research, etc.)

Depending on the subject of study, the further (sub)subsystems are filled in more specifically. For example for competitiveness of a region for a community (I) you can use factor conditions (A), demand (G), related industries (I) and firm strategy (L). This is the Porter scheme (Porter M. , 1990) (Porter M. , 1999), which is widely used in business administration and which is in turn related to more literature. Here we have a good basic scheme with elements that, as we will see in a next paragraph, correspond to the quadruple helix.

A system does not only consist of objects but also of relationships between objects or subsystems. Through these relationships objects or subsystems communicate by means of media and in this way, they influence each other. One can try to reach agreement by means of language, but that is very cumbersome in the economy with barter. That is why there is the generic medium of money. If a police officer must enter discussion with every fine that is also cumbersome and so it is then the medium power that makes the offender pay. Regarding the social system, there are the following four generalized symbolic media: A: (Economy): Money. G: (Political system): Political power. I: (Societal Community): Influence. L: (Latency system): Value-commitment. As mentioned, the social system is part of a larger whole and each subsystem can be subdivided again, as for example in politics into legislative, executive and judicial power, as well as the federal law (Kerkhoff, 2007); (Hofman, Foks, & Kokhuis, 2000); (Hofman, 2018); (Hofman, 1998). They have their own media.

It is worth pointing to McLuhan with (McLuhan, 2002) (McLuhan & Powers, 1989): "The instance of the electric light may prove illuminating in this connection (of media). The light bulb is a clear demonstration of the concept of "the medium is the message": a light bulb does not have content in the way that a newspaper has articles, yet it is a medium that has a social effect; that is, a light bulb enables people to create spaces

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

during nighttime that would otherwise be enveloped by darkness. The same goes for new media like the internet, which is often used in the quadruple helix because it can accelerate information around innovation. The internet medium itself has no content but does change the world. It gives a different dynamic to the symbolic media of Parsons but they themselves do not change. New media bridge distances easily and make the world 'smaller', but proximity between people remains important in some cases.

2. The Triple Helix

This paragraph will focus on the main points of Leydesdorff a Dutch sociologist, cyberneticist and communication scientist at the University of Amsterdam, known for his work in the Triple Helix model of innovation (worked together Etzkowitz in the 1990s Wikipedia).

Three themes have been central to my research program: (1) the dynamics of science, technology, and innovation; (2) the scientometric operationalization and measurement of these dynamics; and (3) the Triple Helix (TH) of university-industry-government relations.

University-industry-government relations provide an institutional infrastructure carrying the potential of self-organization in the knowledge base of an economy. I elaborated these themes into the problem of relating (i) Luhmann's sociological theory about meaning processing in communications with (ii) information-theoretical operationalizations of the possible synergies in Triple-Helix relations, and (iii) anticipatory mechanisms in cultural evolutions. (Leydesdorff, 2020)

A key issue is the scientometric operationalization and measurement of the dynamics. Leydesdorff starts with an elaboration of the of Shannon – Weaver model what is criticized for its simplicity. But Leydesdorff made useful additions.

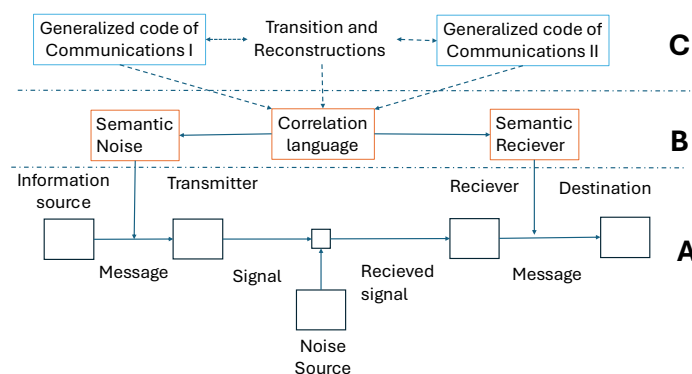


Fig. 2 Level A Shannon – Weaver, B and C added to the Shannon diagram Source: (Leydesdorff, 2020)

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

In addition to the Shannon -Weaver model Leydesdorff proposes the levels B and C: meaning is conveyed at level B, and the received meaning can affect behavior from level C.

The relations among a *semantic* receiver and *semantic* noise at Level B are based on correlations among sets of relations at level A. At constructions at level B, meanings can be shared, while information continues to be communicated in the links at level A. The use of language facilitates and potentially reinforces the options for sharing (and distinguishing!) meanings at level B. Natural languages provide opportunities to develop semantics; symbolic meanings, however, require codes to operate in the communications. Codes of communication are invoked from level C for regulating the use of language. The codes enable us, among other things, to short-cut the communication (similar as Parsons media, but also includes tacit rules of a paradigm).

Whereas a psychological system operates in terms of individual consciousness and tends towards integration (also basic assumption Parsons) a communication system can be expected to remain distributed. As a next-order system, the communications can thus provide a regime to the communicating individuals developing along historical trajectories. Since communication systems are not biologically alive, they do not need to be integrated and constrained in terms of life-cycles.

There can be a selection and coordination mechanisms leading potentially to trajectories as stabilizations of the uncertainty over time. Codes in the communication add one more selection mechanism for stabilization. Because the second-order selections (regimes) select on the second-order variation (stabilizations along trajectories) in parallel to first-order variations and selection, the operations loop into themselves and one another with the resulting complexity and the possibility of self-organization can lead to unintended consequences. The loops are not hierarchically organized but can interact and thus disturb one another. Both the historical trajectories and the evolutionary regimes can be expected to change, but at different speeds or, in other words, without a priori synchronization.

Referring to Dosi and Kuhn (Kuhn, 2013) Leydesdorff states

In broad analogy with the Kuhnian definition of a “scientific paradigm,” we shall define a “technological paradigm” as “model” and a “pattern” of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies.[...].

As “normal science” is the “actualization of a promise” contained in a scientific paradigm, so is “technical progress” defined by a certain “technological paradigm”. We will define a *technological trajectory* as the pattern of “normal” problem solving activity (i.e. of “progress”) on the ground of a technological paradigm.

But Dosi did not elaborate specifically the *evolutionary model*. Changes at the regime level happen beyond control; changes at the trajectory level can be organized by an agency (e.g., entrepreneurs).

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

The tension between historical organization and evolutionary self-organization is articulated in the sociology as the difference between “group” and “field” as indicated by for example, Bourdieu where each field (discipline) is the site of a specific legality, a product of history, which is embodied in the objective regularities of the functioning of the field; the mechanisms governing the circulation of information. Leydesdorff makes also reference to Popper (world 3) and Hussler. For this paper it is also interesting to mention the pattern variables from Parsons (Turner, 1999) (Kerkhoff, 2007) where in the action orientation of a person in a relationship within a social system someone acts depending on the social role that he or she fulfils, regardless of personality and circumstances. That is also guided by level C which can be seen in Parsons’ human condition, what is no part of this paper.

The exchange between domains of academics, companies and government in the triple helix is then due to Leydesdorff (in line with Luhmann) the translation between the (sub) systems. The way to get knowledge in the helix is looking at citations that scientists, companies and government makes among themselves in the various domains (scientometric (Leydesdorff, 2020)). The information is useful but limited. For that reason Hofman and Burgmans (Hofman & Burgmans, 2005) proposed the possibility of tracing the Triple Helix back to sociology with the AGIL-schema of Parsons, using insights from communication sciences but also more broadly from sociology. In the subsystem on the bottom right, Porter’s competitive forces model has been used, but there are more possibilities to use this subsystem depending on the perspective of the study, also at the geographical level. Various studies and insights from the different domains can be used from different perspectives using clear system boundaries (Hofman, Foks, & Kokhuis, 2000). Still scientometric can be used if the researcher takes this perspective. In fact, this provides already the picture of a quadruple helix.

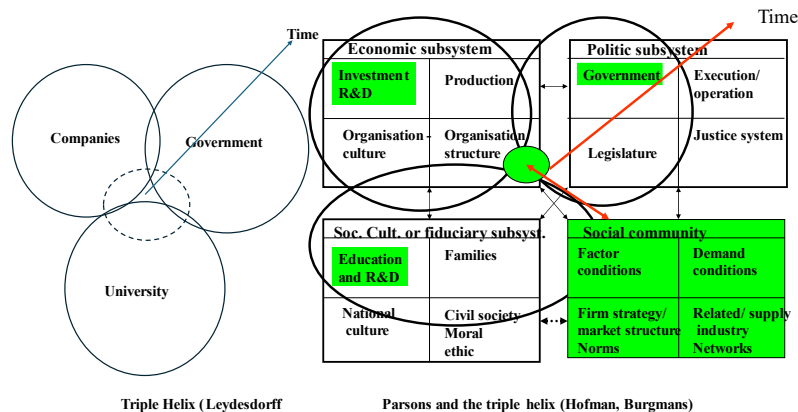


Fig.3 Triple helix projected in AGIL scheme of Parsons (Hofman & Burgmans, 2005)
 The three elements of the triple helix are in the AGIL scheme and the scientometric operationalization can be included as an aspect system in that scheme. As for the integration part, the situation for companies has been examined for which the growth

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

diamond of Porter is included providing an additional perspective. This can also be filled in with civil society providing the perspective the quadruple helix advocates.

3 Habermas and Luhmann

Important is the perspective that Leydesdorff takes within the Habermas Luhmann discussion. The theories are embedded in Kant's philosophy and the categorical imperative ; 'Act only according to that maxim whereby you can at the same time will that it becomes a general law'. Habermas states that for that law we need a discourse to reach agreement about that law. Not everyone thinks the same about what you would like as a general law. But Leydesdorff follows the line of Luhmann in the Habermas versus Luhmann debate:

Note that both Habermas and Luhmann called for a theory of meaning as foundational to sociology. However, Habermas elaborated this theory in terms of communicative *action*, whereas Luhmann theorized communication *structures*. In Marxism, action provides a way to change structures, but this relation between action and intended changes had become less obvious given the increased complexity of an increasingly knowledge-based economy. (Leydesdorff, 2020).

In Habermas's view, modern societies are based on two types of social order: the lifeworld and the system. The lifeworld concerns the social order of individuals who consciously commit themselves to certain norms as a guideline for their actions. In systems, actions are not primarily coordinated through communicative action, but through strategic action. In systems such as the economy and the state, individuals are not so much moved to coordinate their actions by convincing others with arguments, but by inciting them to do something with money or by using power to persuade them to do something. In his model of communicative action, he proposed a power-free discourse of citizens in which truth, justness and truthfulness is applied¹.

Luhmann viewed modern society as a vast network of autopoietic systems, each having its specific concerns, communication styles, and operations. An essential condition for the existence of a system is the ability to (re)create itself (autopoiesis). The core principle in Luhmann's sense is: if it does not make itself, it is not a system. Luhmann referred to the concept of the neurobiologists Maturana and Varela. Within these systems, they communicate with each other by translating their language into the understanding of the receiving system, like a person translating their communication for effective interaction with someone who speaks a different language. These complexities of advanced modern society arise from the coexistence and interaction of diverse systems, each possessing its unique perspective and operating principles. For example: a high-tech company (economic system) likes a new scientific discovery (scientific system) to create a new product. Together they need to translate the

¹ For more information see <https://plato.stanford.edu/entries/habermas/#RelaLifeSyst>

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

scientific information into terms that makes sense in the economic world with the language around cost effectiveness and market demand.

In general Habermas is more in line with the ethics of Kant (personal duty). But the arguments of Luhmann are also useful and in line with the perspective of Leydesdorff 's triple helix about the systems university, government en companies, which is complex and were acting in a fixed paradigm without discourse as intended by Habermas. It are precisely those difficult to find structures, who work differently in university environments for fundamental research and global companies, that Luhmann points out that must be recognized and not denied in order to obtain a healthy region with a quadruple helix.

4. Innovation and learning

The triple and quadruple helix is about innovation and therefore about knowledge and learning. Starting with two definitions, this paragraph will delve a bit deeper into learning.

- Innovation is any idea, practice, or object that is perceived as new by an individual or other unit of adoption (Rogers, 2003)
- Learning is the process of acquiring new understanding, knowledge, behaviors, skills, values, attitudes, and preferences (Gross, 1996).

An idea or practice can be scientific, put into practice or developed by users themselves. Learning can be done at different levels, such as strategy with vision development or carrying out practical matters and in different ways such as watching what babies do to master operational matters. Sometimes one is deepening a certain subject and creatively developing new vision and strategies. In the quadruple helix, all partners and particularly by the residents elected government (goal attainment Parsons) are the owners of that process. If you set up that learning process well, then the outcome given the circumstances is the most optimal. If you set up that process only to copy what you have always done, you always get the same thing without progress or using new technologies. That causes a relatively downward circle if other regions master that learning and development process and adapt from their position to new more advanced environments.

This section consists of four subsections.

4.1 Three stroke learning (Swieringa & Wierdsma, 1996)

According to Kant (Kant, 2004) we can't know everything but the question for him was whether we do enough to gather the necessary knowledge. Kant had the impression that people were too lazy. That doesn't seem to have improved much since Kant in the 18th century. For a good regional analysis more insight and knowledge finding is often needed, than just what one observes in daily operations, one tells each other in interviews, Facebook and X. It is important to distinguish between the types of knowledge to set up an adequate learning process that fits the right problem for the region.

4.2 Tacit knowledge (Nonaka & Takeuchi, 1995)

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

Not all knowledge is explicit and easily transferable via media such as the internet. Proximity is often also important, especially in innovation. In knowledge hubs, knowledge workers always cluster together to develop new knowledge. The process of getting from tacit to explicit knowledge that can serve as a 'unique selling point' is important in a region.

4.3 Novelty and absorption level (B. Nooteboom, 2008) (B.Nooteboom, 2004)

Not everything that comes along is suitable as a unique selling point for every region. There are often hypes around internet, big data, robotization, AI or creativity after which many cities and villages want to become creative cities (Florida & Harris, 2003) with the same elements mostly ICT as in Silicon Valley. That is copying. The deeper background, Nooteboom propose, lies in the advantages of cognitive distance, what a region can absorb. Cognitive distance presents a problem and an opportunity

4.4 Change in the AGIL scheme (Parsons & Toby, Evolution of societies, 1977)

The criticism of Parsons is that he would not have paid attention to development. This last part briefly indicates that this is incorrect.

4.1 Three stroke learning (Swieringa & Wierdsma, 1996)

In the learning organization they use a three-stroke model for learning, including norms and values.

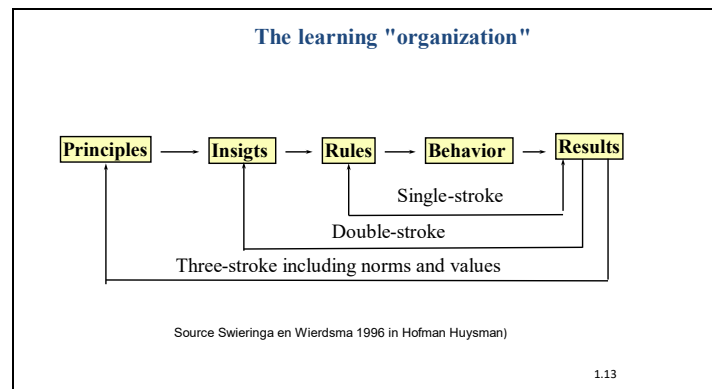


Fig.4 The learning organization (Swieringa & Wierdsma, 1996)

1. Single-stroke learning leads to a change in existing rules (or: learning at the rule level)
2. Double-stroke learning is learning in which not only a change in the rules, but also in the underlying insights is involved (or: learning at the insight level)
3. Three-stroke learning is learning in which, in addition to rules and insights, the essential principles on which the organization is based are also discussed like learning at the identity level with norms and values.

Critical reflection is a process by which one may identify the assumptions governing one's actions, question them, and develop alternative behaviors. Leydesdorff is right that there are processes at play at the evolutionary level and 'Habermas elaborated this theory in terms of communicative *action*, whereas Luhmann theorized communication

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

structures'. But we need both. A theory and research into structures but also, partly based on that, a theory to come to action. And to be successful in a quadruple helix, recognizing that structure and act on that, the three-way learning is of essential importance.

Important is also the 'awareness of gaps between what Schon and Argyris (Argyris, Putnam, & McLain Smith, 1985) term "espoused theories" and the "theories-in-use" that actually guide people's practice. The same can be observed when we look at how people deal with ideologies but (Eagleton, 2024). But we need to bring the "espoused theories" and the "theories-in-use" into line with each other more consciously. To say that there is an evolutionary system that influences society without discussion comes close to saying that there is a religion where a God has influence what you should accept uncritically. Kant places that responsibility precisely with the human being who is also obliged to do rational research based on the categorical imperative. That is the theory in use; the time of Enlightenment in which we say we live. And although with the new media there is an abundance of information to analyze, the reality is that people often remain in their own (virtual) bubble, without working on a new structure for a power free discourse outside the bubble. The pitfall is that people say they act innovatively in the quadruple helix and want to learn, but continue to act in the first -stroke learning in the same way as they always did.

4.2 Tacit knowledge (Nonaka & Takeuchi, 1995)

As McLuhan (McLuhan, 2002) (McLuhan & Powers, 1989) pointed out, the media changes the message, but new technology in general also changes society (Ihde, 1990) (Achterhuis e.a., 1997) (Achterhuis, 1992). Copying behavior within the region can make a region strong. In Eindhoven you are confronted with technology at a young age because the 'environment is technology' and most Eindhoven residents are trained in technology. Unconsciously, behavior is copied. But technology changes the world. Even then, what you learned is important, but it is then also important to become aware of the intrinsic knowledge (make it explicit) so that you can combine it with new explicit knowledge, in this case via new media, big data and AI that is easily transferable, to new combinations that are favorable for the region.

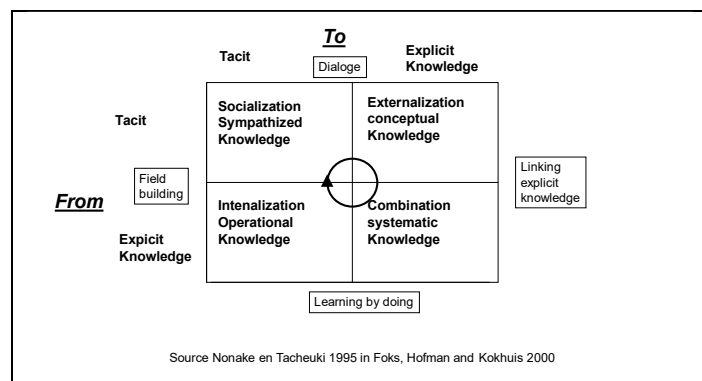


Fig.5 Four modes of knowledge conversion (Nonaka & Takeuchi, 1995)

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

Nonaka & Takeuchi, (Nonaka & Takeuchi, 1995) introduced four modes of knowledge conversion. First *socialization* (Tacit to Tacit) a process of sharing knowledge, including observation, imitation, and practice. It is about capturing knowledge by physical proximity, wherein direct interaction is important, with customers and/ or in or between organizations (including norms, values and even operate in a in a good reflective and critical way). The next step is *externalization* (Tacit to Explicit) the process of making tacit knowledge explicit. Knowledge is crystallized and thus able to be shared by concepts, images, and written documents. With this you can *combine* (Explicit to Explicit), integrate and merge types of knowledge. The creative use of computerized communication networks and large-scale databases can support this mode of knowledge conversion. *Internalization* (Explicit to Tacit) involves learning-by-doing. Internalization is also a process of continuous individual and collective reflection, as well as the ability to see connections and recognize patterns, and the capacity to make sense between fields, ideas, and concepts.^[4] This is a clockwise continuous process.

It is important to emphasize the socialization in which critical thinking and ethics are important, and tacit knowledge is transferred that is not in paper or internet. The implicit knowledge that is used in the socialization process can be unique. Explicit knowledge can be applied quickly all over the world via new media, and you can *no longer distinguish yourself as a region*. From this it follows that it is especially important for three-way learning to analyze in which area socialization takes place, so which relatively unique activities there are in the region where people 'unconsciously copy each other'.

4.3. Novelty and absorption level

The question is of course to what extent man can take on new elements for innovation. That depends on the level of knowledge there is already and the extent to which the new thing is new for the person or group in question.

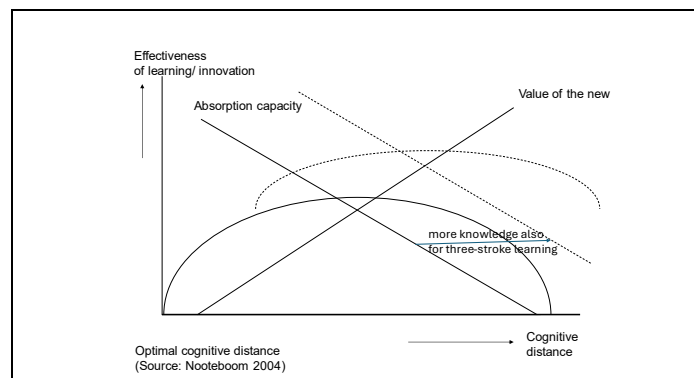


Fig.6 Optimal cognitive distance

Nooteboom (B. Nooteboom, 2008) points to innovation that often includes Schumpeterian 'new combinations', which indicates that an important source of innovation lies in cooperation between people or companies with different knowledge.

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

This means that companies should not try to innovate in isolation, but in cooperation with others. This gives efficiencies of scale and scope and is especially important for innovation, a greater diversity and flexibility for the new combinations.

The deeper background, we propose, lies in the advantages of cognitive distance. Cognitive distance presents a problem and an opportunity. Cognition here relates to both rational and moral dimensions of cognition, to knowledge and judgment. The problem is that cooperation becomes more difficult as the distance increases, because people understand each other less well (less suitable absorption capacity) and have different views on cooperation. The opportunity lies in the fact that the difference offers an opportunity to learn something. Innovation is promoted by a balance between difference and agreement, in optimal cognitive distance: large enough to tell each other something new, but not so large that people cannot understand each other. This is illustrated in **fig 6**. The descending straight line shows that it is more difficult to cooperate and understand each other as the cognitive distance increases (more knowledge provides more effectiveness; line goes to the right; new U curve). The ascending straight line shows that the novelty value of the relationship increases.

The inverted U-shaped shows an optimal cognitive distance. This view is in line with the weak ties theory of Granoveter and the scaffolding learning from Vygotsky (Miedema, 1997). Please note that Nooteboom sees values and virtues here primarily in the context of businesses, whereas in this paper the values of society (and social studies) also require attention. In this respect, competition is based on differentiation, not only for companies but also for regions. On several parameters, regions must achieve a certain minimum score to be able to participate. There is therefore convergence (generic) and divergence (specific) knowledge (Jacobs, 2002). And the content of that generic knowledge changes too. In the past, working with the slide rule was basic knowledge; now it is working with the computer, Excel, Chat gtp and handling big data. That together with specific experience of the region makes new combinations.

In summary, it is important to think about the rules and insights, the essential principles on which the region is based, built up from history (three-step learning). There are always potential possibilities from tacit knowledge and experience. The next question is which new technology can be added from outside, which sufficiently matches the potential of the region to arrive at new combinations. In addition to generic knowledge that always must be at the right (state of the art) level, specific knowledge can be added to increase the absorption level and give the region sufficient distinctive capacity for competitive strength and employment.

4.4. Change in the AGIL scheme

Finally, within de AGIL scheme change in the rate or direction of process is a consequence of disturbance in the relations between the actor or acting systems and the situation or meanings of the objects. Whatever its source, disturbance will always show

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

up in the form of strain. What difficulty in the attainment of value goals stated, states from this point of reference may be distinguished 2 fundamental types of processes.

1. Performance processes these are processes by which the disturbance is eliminated or adequately reduced through adaptive mechanisms leaving the integrative standards, the most directly vulnerable aspect of the structure of the system unchanged. The process may be adaptive in either the passive or active sense that is through adjusting to changes in environmental exigencies or achieving mastery over them. The basic paradigm of this type of process is the means end schema the direction of such process is clockwise relative to goal focus from **A to G**.
2. Learning process or processes of structural change in the system. Whatever the source, this disruption is transmitted to the integrative standards themselves, and forces shifts in their categorization and in their relative priorities. Whereas in the performance processes above goals are given in the learning process, here they must be redefined. Relative to the goal focus, this direction of such a process is counterclockwise from **I to G**.

To be stable in the long run a system of action needs a generalized adaptive relation to its environment related to the specific goal status. To preserve its own normative control in the face of environmental variability the system must be related actively. This is like the learning steps to keep a business and the region going.

5 Network oriented modelling for adaptive networks

‘This is a world where massive amounts of data and applied mathematics replace every other tool that might be brought to bear. Out with every theory of human behavior, from linguistics to sociology’ (Leydesdorff, 2020). Leydesdorff also uses data from databases with scientometry, but seems to reject the philosophy of Damasio (Damasio, 2012) and neurobiology with big data. This might be a bit too simple

Starting with neurological models (Treur, 2020) it is possible to model influence also in connection at higher order levels (like Leydesdorff) with Parsons in the baseline (Hofman & Treur, 2021). By indicating the structure with the influence that objects or nodes exert on each other, more insight can be gained into the course of the process in time (flow as mentioned in the introduction; Leydesdorff is more stock). This was done as a first step in a model where two regions were compared with each other using an economic target as a basis (Hofman & Treur, 2021). For the basis Parsons' reference scheme for the social subsystem was used. For the first-order adaptation level, Hebbian learning is used (Treur, 2020) and for the second-order adaptation level, the speed of learning is influenced by the underlying culture (loosely inspired by how plasticity and metaplasticity are analysed as first-order and second-order adaptation within neuroscience). This is done for the two basic nodes I and A, where the parameters were kept the same for the sake of clarity. The connectivity of the network model is given in **fig. 7** and in Table 1 its states are briefly explained.

Following Treur (Treur, 2020) a temporal-causal network model is characterized by here X and Y denote nodes of the network, also called *states* with activation values $X(t)$ and $Y(t)$ over time t :

- **Connectivity characteristics** **Connections** from a state X to a state Y and their weights $\omega_{X,Y}$ (for example influence X to Y).

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

- **Aggregation characteristics** For any state Y , some combination function $c_Y(\cdot)$ (usually with some parameters) defines the aggregation that is applied to **the impacts** $\omega_{X,Y}X(t)$ on Y from its **incoming connections** from states X (Y gets influence for more relations which can have different impact on Y).
- **Timing characteristics** Each state Y has a speed factor η_Y defining how fast it changes for given impact.

For equations see (Hofman & Treur, 2021) on ResearchGate. There is a library of many functions available for Matlab. Table 1 shows the nodes at the different levels shown in the figure. Although not used here, it is also possible that nodes at a higher level interact with each other. To determine what can be used, the Hebbian learning function² with certain variables can be used to make predictions for the future, if no unexpected disturbances occur. This is just a brief illustration of a model that could well illustrate the relation of forces used by Leydesdorff in figure 2 paragraph 2, however without using scientometric (less relevant voor region Alkmaar) in this case.

Table 1. State names of the network model including the states A, G, I, L from Parsons at the base level, and the **W**-states and **H**-states for learning at the first- and second-order adaptation level.

State nr	State name	Name	Explanation	Level
X ₁	A	Adaptation	Economic target state	Base
X ₂	G	Goals	Political instrument state	
X ₃	I	Integration	Network state	
X ₄	L	Legacy	Pattern maintenance or ‘cultural state’	
X ₅	W _{IA}		First-order self-model state for Hebbian learning for connection from I to A	First-order Adaptation
X ₆	W _{GI}		First-order self-model state for Hebbian learning for connection from G to I	
X ₇	H _{IA}		Second-order self-model state for speed factor (learning rate) for W _{IA}	Second-order Adaptation
X ₈	H _{GI}		Second-order self-model state for speed factor (learning rate) for W _{GI}	

² Neurons that fire together, wire together is the most simple explanation of the rule of Hebb, but this can be given in functions (Wikipedia and (Treur, 2020)).

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

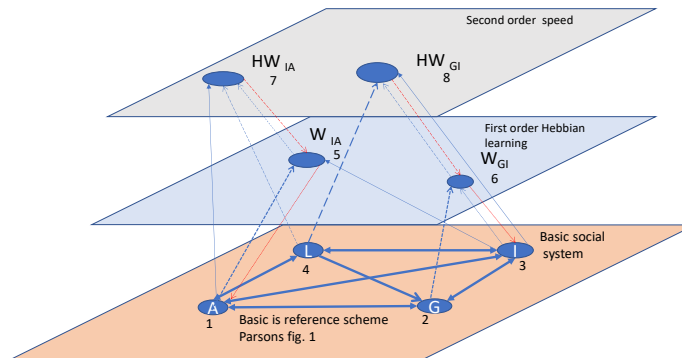


Fig. 7. The connectivity of the introduced second-order network model and with Hebbian learning at the first-order adaptation level (first-order self-model **W**-states) and second-order adaptation level (second-order self-model **HW**-states)

With these models it is possible to analyse processes where scores only reflect the situation. However, it is important to determine the initial values of the nodes and the functions with the variables. Scientometrics could contribute to establishing those initial values but more in general also information from big data. This certainly requires further research and is beyond the scope of this paper.

6. The Quadruple Helix

After the Leydesdorff triple helix the quadruple helix develops, which this paragraph briefly discusses. Leydesdorff:

‘In sum, the Triple Helix can be related as a theme to theoretically and methodologically interesting questions and has become a meeting place for scholars from different disciplinary backgrounds with the aim of contributing to the improvement of innovation systems. The call for quadruple, quintuple, and next-order configurations has remained one that can be combined with other metaphors such as “responsible innovation” in “smart regions” which legitimate funding decisions but have hitherto not yet to offer substantive newness and research perspectives.’ (Leydesdorff, 2020)

This statement seems correct from his perspective (Leydesdorff & Lawton Smith, 2022) because the following helices ignore the communicative layers and the Habermas-Luhmann philosophies that he used as a basis. Civil society and later the environment is added, but the question is whether they perceive and experience history and evolution in the same way as Leydesdorff does and small regions without a university for fundamental research still gets little attention.

The article ‘Micro- and Macro-Dynamics of Open Innovation with a Quadruple-Helix Model’ explores how sustainability can be achieved using in a literature and practice review (Yun & Liu, 2019). ‘Traditionally, sustainability is articulated as the triple-

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

bottom-line framework of economic, environmental, and social dimensions. But in the current era of the 4th industrial revolution, the internet of things, the shared economy, and the implementation of artificial intelligence has started to affect firms, supply chains, and the whole ecosystem' (Yun & Liu, 2019). (fig. 8).

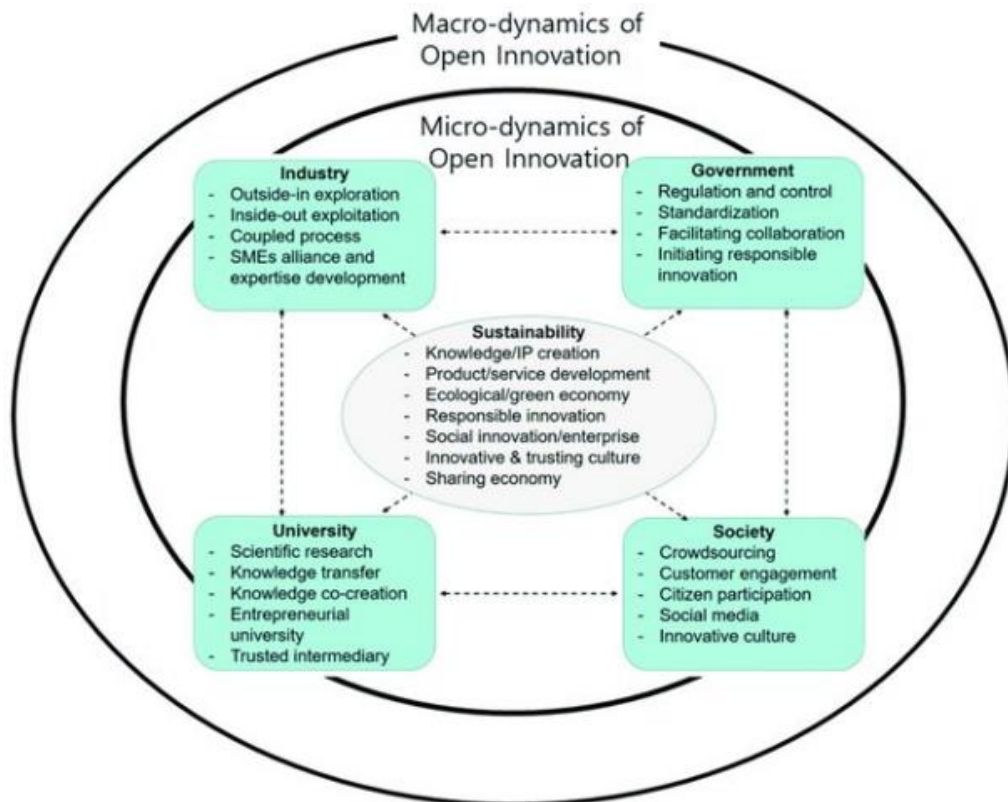


Fig. 8 Micro- and Macro-Dynamics of Open Innovation with a Quadruple-Helix Model' (Yun & Liu, 2019)

'As for the future research, firstly, from the open innovation micro-dynamic perspective, this conceptual model needs to be further validated'. Where 'Case studies from diverse industries, regions, and nations can further develop and enrich the "open innovation micro-dynamics" and finally the model will be developed by diverse concrete studies, to conquer the growth limits of capitalism' (Yun & Liu, 2019).

With Parson's scheme, this paper indicates that society is more 'conquer the growth limits of capitalism' customer demand and information system for marketing.

There are social concepts for smaller regions that can further develop and enrich models for innovation for micro dynamics. The definition of innovation (paragraph 4) is relevant in this case.

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

Also, a further interpretation of the concept of democracy in the context of the quadruple helix, as mentioned in 'Democracy and the Environment: How Political Freedom Is Linked with Environmental Sustainability' (Carayannis, Campbell, & Grigoroudis, 2021), requires further research. Here too, Habermas has placed a commentary on society in the context of the new media (Habermas, 2023). This falls outside the scope of this paper, as also figures as generated by the EU to indicate progress. For example, an overview of 2024 for the Netherlands; Foreign doctorate students as a % of all doctorate students has increased from 76 points since 2017 to sky high with 296 which is indicated as positive. The usefulness of such a high level can be doubted and requires further explanation. The government is currently working on reducing the number of foreign students because the balance is out of whack. These kinds of numbers need to be interpreted in the context of what type of students are useful in the regional environment, as indicated in this paper also for a smaller region.

This paper started from scheme in which a multitude of theories and models, concerning people and society can be fitted depending on the question and the perspective of a researcher or research. Definitions from several disciplines can then be used, whereby the triple helix is an aspect system for universities and companies based on the theory of Leydesdorff. Quadruple, quintuple, and next-order configurations can also be studied in that scheme, whereby scorecards show the situation at a particular moment (social capitals), which can be derived from ICT (also where Leydesdorff gets his information). But within the communication channels, the relationships and the adjustments in a system also play a role, as indicated in network analyses (paragraph 5). There must be room for broader knowledge development than just in universities so that the scheme can also be applied to regions without a university for fundamental research and companies with R&D. In the table below the quadruple helix and the AGIL scheme are placed side by side. The subsystems in the AGIL scheme can be filled in with various theories. This seems a more multidisciplinary, flexible and integral tool voor studying regional innovation for every region on its own level (Hofman, Foks, & Kokhuis, 2000).

quintuple helix		AGIL reference scheme Parsons		
<i>Subsystem</i>	<i>Capital</i>	<i>Subsystem</i>	<i>Medium</i>	<i>AGIL</i>
economic	economic	economic	Money	Adaptation (A)
political	political	politicians and government	Power	Goal (G)
media-based and culture-based public (also 'civil society')	social capital and information capital	social community (I) is the integration	Influence	Integration (I)
education	human capital	pattern maintenance	Value-commitment	Latency (L)

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

In addition, pattern maintenance is again composed of the subsystems rational subsystem (divided in general (*universities*), training for applied profession and others) (**A**), telec system (with family) (**G**), moral community (**I**) and civil religion as constitutive of values (**L**). So, knowledge and learning are situated here in a broader context than just the university (scientometric operationalization and measurement), which seems right because innovation is not separate from other levels of knowledge and the education of young people in general.

Summary and conclusion

Parsons, indebted to the philosopher Immanuel Kant, is one of the founders of systems theory, with Habermas and Luhmann following in his footsteps. The triple helix of Etzkowitz and Leydesdorff take a specific perspective for universities, industry and government. The core idea of communication theory is useful and scientometrics as an aspect system of the social system meaningful for universities, companies and government in the context of innovation for regions with a strong international knowledge infrastructure. However, two elements are missing: the analysis options for smaller municipalities without a university for fundamental research and companies with a specialized R&D and the broader social context that is also important for innovation and citizens in general.

The AGIL scheme provides an excellent frame of reference to contextualize these systems, within which the triple helix can be an aspect system. The higher order systems that Leydesdorff indicates for the triple helix can fit in there and worked out for further research using dynamic network models (Hofman & Treur, 2021) . Interconnections are important in that research and network theory can contribute to that.

Leydesdorff distances himself from Habermas and follows Luhmann, who states that the power-free discussion within today's complex society is not possible. This is indeed a challenge, but Habermas' starting point is in line with Kant, who asks the question 'How should I act' which is not in the scope of the triple helix. These ethical questions becomes more important with the current complex society with increasing influences from large tech companies and it seems wiser to sharpen the vision of Habermas through further research instead of ignoring this perspective.

The triple helix mainly puts innovation at universities and companies in the front, but there is a lack of a relationship towards users, citizens and regional society. Innovation is learning new insights and knowledge, whether this concerns research at university, at primary school or among citizens who are not yet familiar with for example heat pumps. Learning also concerns intrinsic knowledge that in many cases is even more difficult to transfer via media such as the internet and therefore requires personal contacts that cannot be measured via scientometrics. Since most people work and live outside university knowledge regions, further research is needed into developments in those environments. In general, learning in the context of norms and values is an important aspect that requires more attention than in the triple helix.

The Quadruple Helix: theoretical arguments for a small EU Reformers region like Alkmaar

Starting from Kant, it is justified to use analogies from neurology in social science if it has been empirically proved that the image of the analogy is correct. Models from neuroscience are therefore useful if they are used correctly. Using network-oriented modeling for adaptive networks provides the opportunity to visualize (future) processes (flow) in addition to scorecards (balance sheet) using power and influence in these processes. However, this approach is still in its early stages and it always remains difficult to predict, especially when it concerns the future with unexpected events.

Ultimately, the quadruple and quintuple helix seem to approach many social aspects from an innovative and ICT perspective at university level. But to also provide other regions with a scheme and to prevent alienation among those groups, it seems useful to take the sociological AGIL scheme as a basis and to include all other issues and helices as sub-aspects. Many issues that are included in the helices are similar, only the AGIL scheme refers more to social elements and other useful theories fit in well. The latter will require further research.

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