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Orchestrating a New Industrial Field. The Case of the Finnish Wood-Based Bioeconomy

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Abstract

The article's focus is on how companies and institutions interact and cooperate in order to develop the wood-based bio-economy field. Based on a case study of the Finnish forest sector, the paper shows that shifting to sustainability requires processes of co-creation. As radical innovation requires complementary competences, companies have had to cooperate with a large number of actors. By interacting with multiple actors at multiple levels, both companies and institutions have engaged in new types of activities that have led to a change in their respective roles. By taking on responsibility for developing the new industrial field, both companies and institutions act as orchestrators for mobilizing a large number of public and private actors. Subsequently, the paper argues that this interaction has produced a new type of complementarity between companies and institutions facilitating the development of the new industrial field.

Keywords:

Forest industry companies; bioeconomy; biorefineries; start-ups; national innovation system; co-creation; sustainability; actor-centred institutionalism; dynamic complementarities.

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1 Introduction

In the ongoing transition to a sustainable economy, the Bio-Based World News has named Finland a world leader in the forest bio-economy (Bio-Based World News, 2016). As Finland is Europe's most heavily forested country with 86 per cent of its land area under forest cover, the country has taken strategic moves to make use of her 'green gold' for 'the green shift'.

The Finnish state pursues a holistic policy for promoting sustainability, but key actors in transforming the forest industry are the largest Finnish forest industry companies that have a long track record in utilizing this renewable resource. Together with a broad group of public and private actors, they head the development of new, higher value added bio-based products. The transformation is characterized by the development of a wide scope of new bioeconomy businesses reflecting the combination of different technologies and disciplines. New products and businesses span from biofuels and bioconstruction materials to biochemicals, consumer products, and products for the health sector. At present, the bio-economy accounts for 26 per cent of Finland's total exports and 13 per cent of her employment.

The objective of this article is to expound crucial mechanisms that enable the growth and development of the Finnish wood-based bio-economy. At the industry level, the turn to a bio-based economy represents a shift from incremental to radical innovation. This shift also involves a move from considering innovation as an isolated and shielded activity to consider it a collaborative process in open innovation systems. At the institutional level, open innovation represents a shift from bureaucratic managerial procedures to decentralized experimental approaches. Co-creation, in which companies collaborate with suppliers, distributors and customers in addition to research institutes and regulatory authorities, has

been essential for detecting novel interests and value. Such processes have also been essential for mobilizing cross-disciplinary knowledge and competences.

Arguably, the accomplishment of the wood-based bioeconomy depends on the effectiveness of co-creation processes. An important finding in the study is that successful co-creation has its origin in an institutional invention. Companies in collaboration with research institutes and universities have established new and unique forms of partnerships in the form of joint stock companies. These companies not only facilitate co-creation processes, but are also responsible for developing research programmes. In this capacity, the public-private partnership companies represent an institutional invention to transform the national management strategy for innovation. Another important finding is that both private companies and public institutions have engaged in new types of activities, and through accumulated competences have changed their role. This inter-linked role change made processes of co-creation effective.

To ground this claim theoretically, in line with comparative institutionalism, the article maintains that new complementarities have evolved. It also argues that these complementarities strengthen the functioning of new institutional configurations, as institutions and actors have learned from each other and adapted to a changing environment. Thus, at the theoretical level, the article claims that complementarities constitute a key mechanism in the emergence of the bio-economy field. To support this argument methodologically, the article adheres to an actor-centred institutionalist approach. The actor-centred approach makes it possible to use an epistemology that does not attribute stable roles for actors (Mayntz and Scharpf, 1995), but one that emphasises the experimentalist role of actors and that actors and institutions mutually constitute each other (cf. Kristensen and Morgan 2012, p. 421).

The structure of the article is as follows: the next section positions the article in actor-centred institutionalism, the third section gives an overview of the forest industry, information about case companies and institutions, and data collection. The fourth section gives illustrative evidence of new forms of collaboration and co-creation processes. The fifth section exemplifies companies' and institutional actors' new roles. The sixth section summarises and discusses the experience of the emergent wood-based bioeconomy in Finland.

2 The article's theoretical positioning

For explaining the emergence of the wood-based bioeconomy field, the term complementarity is utilized in order to capture the key mechanism. As the term is generally used – explicitly or implicitly – in comparative institutionalism, it grounds one explanatory model in this research tradition. It refers to the fit between institutions and between institutions and societal actors in several theoretical frameworks. In comparative studies of national business systems, innovation systems and entrepreneurship, the term is used for explaining distinct types of actor behaviour and outcomes (cf. Freeman, 1995; Whitley, 1999; Hall and Soskice, 2001; Ács et al., 2014).

An essential characteristic of institutional complementarities is that, in a democratic capitalist society, complementarities emerge across institutional settings, sectors and action systems without a grand design. They are recognised post hoc, and taken to contribute to improving the functioning of specific institutional configurations (Amable, 2016). In coordinated market economies, such as that of Finland, various societal stakeholders, industrial firms and banks used to be strongly interlinked. The nature of these interlinkages is seen to hinder institutional change and to only support incremental innovation (Hall and Soskice, 2001; Whitley, 1999). In contrast, the arm's length sort of coordination in liberal market economies is seen to give space for rapid change due to extensive reshuffling of people and resources supporting radical innovation. Even though the notion of complementarity underlies all theories and models of institutional systems or regimes, its dynamic aspect, or lack of it, is under-problematized.

In evolutionary settings in which a new industrial field emerges, such as the Finnish wood-based bioeconomy, institutions, regulations, and standards have to be negotiated across sectoral divides. When incumbent actors from a variety of industries and sectoral contexts recognise new opportunities, they start forming alliances in order to gain agency and for setting rules (Fligstein and McAdam 2012). Actor-centred institutionalism offers a framework for taking into the analysis its various elements: actors, groups of actors and the interaction between actor groups that are involved in the formation of a new field (cf. Scharpf 1997).

At the same time, it emphasises the influence of institutions on actors, their modes of interaction, and how they succeed in changing institutions. In this approach, institutions are systems of rules that structure the courses of action that actors may choose. In actor-centred

institutionalism, the explanatory power of institutions and actor strategies are combined instead of focusing on one or the other. By placing actors and institutions in a process-relational setting, institutions are not simply treated as a given result of a previous evolutionary development, but as something that can be intentionally created and changed through actors' actions (Mayntz and Scharpf 1995, p.45).

As neither actors nor institutions demonstrate stable roles in transforming the forest industry, the article makes use of an epistemology that emphasises the experimental role of actors both in companies and in the national innovation system and, by so doing, actors and institutions mutually constitute each other (cf. Kristensen and Morgan 2012, p.421).

As the current case includes actors both from companies as well as from institutions, actor-centred institutionalism is helpful for identifying actors with specific capabilities and action orientations for mobilizing collective action. The outcome of a particular strategy chosen by a group of actors will depend on the choices of other actors (Scharpf 1997, p.7). Modes of interaction may vary across various action systems as in the forest industry case.

3 The forest industry sector: core actors, case selection, and data collection

The large forest industry companies, and the forest sector more widely, have played a crucial role in the Finnish economy (Lilja et al., 1992). Demand for their key product - printing papers - enabled the companies to attain a strong market position (Moen and Lilja, 2001). During the 1990s, via mergers and acquisitions, they rose to be among the largest pulp and paper companies globally. Leaders in this development were UPM, Stora Enso, and Metsä Group. UPM's main businesses were pulp, paper, adhesive labels and mechanical wood products, including plywood. Stora Enso had strong market positions in the traditional pulp and paper product segments: pulp, paper, and carton board, in addition to mechanical wood. The same was the case with Metsä Group: pulp, carton board, printing paper and tissue, but the Group, like UPM and Stora Enso, was also involved in mechanical wood production.

At the same time as they internationalized, the companies internalized multifunctional operational and managerial competences. With this move, the largest companies transformed from being the epitome of a type of collaborative hierarchy embedded in a collaborative national business system to become isolated hierarchies (cf. Whitley, 2001, p. 41; Moen and Lilja, 2001). Their dominant position was supported by incremental innovation in the form of

technological upgrading of production lines. This took place in cooperation with suppliers, and although the largest companies also had collaborative research with universities and research institutes, they were unwilling to share company specific knowledge (Lilja et al., 2008). Innovation was operated as a closed system in which intellectual property rights were considered a core asset, and new R&D programmes were implemented under top secrecy. Moreover, innovation activities were hierarchically organized and used as support methods for business strategy. R&D input should preferably lead to practical solutions within a time span of three to five years.

When demand for printing paper, for the first time in history, started to decrease in the Western world after the turn of the millennium, the large forest industry companies realized that sticking to their traditional products was no longer viable. Moving into radically new businesses was a big challenge as they had rarely developed new products for new types of customers. Although the research directors of the large companies, through involvement in international research cooperation, realized the need for sharing knowledge with a wide network of companies, there were organizational challenges for corporate makeover (cf. Novotny and Laestadius, 2014). As will be explicated in the next section, it was a structural change in the national innovation system that facilitated the move into an open innovation mode.

As a result of change in corporate strategy, all the three largest companies have developed new businesses based on wood and have integrated sustainability into their business models. UPM, as the first company in the world, has started full-scale production of biodiesel, BioVerno. It has also brought to the market different biocomposite and biochemical products. One example of the latter is GrowDex, a hydrogel providing 3D cell culture for studying how cancer cells react to different types of chemotherapy. Stora Enso, on the other hand, has positioned itself in the production and marketing of pre-fabricated mechanical wood components expected to revolutionize the construction industry. It is also experimenting with new products from lignin. Metsä Group has decided to build the first next generation bioproduct mill in the world, the largest investment in the Finnish forest sector ever. In addition to high quality pulp, it will produce a wide range of bioproducts.

In order to better understand the transformation of the forest sector, the article focuses on these three large companies. As these companies are in the forefront of developing the bioeconomy, they are informative cases. However, as this transformation is the outcome of a

multitude of co-creation processes, institutions within the national innovation system are included in the analysis. This concerns in particular, VTT Technical Research Centre of Finland, the university system and the state funding agencies.

For the study of the companies and the institutions we have used multiple sources of information, including our own field studies starting in the 1980s. Written sources include documents on the internet sites of the companies, research institutes, and universities, such as annual reports and news items. Information about government policies are obtained from published documents. We have also collected newspaper and magazine articles related to the bio-economy field.

The prime source of information, though, has been interviews with key representatives of the companies and of institutions within the national innovation system. These interviews took place over a period of three years. Table 1 provides the number of interviewees linked with the different organizations studied. Interaction with different key actors enabled us to reflect on and triangulate information collected. Largely, the methodology used could be labelled field level ethnography (Zilber, 2014).

Insert Table 1 about here

4 New ways of organizing research and innovation: collaboration and co-creation

Faced with the shift from incremental to radical innovation, companies and research institutes signalled discontent with the way public funding was operated. Tekes, the national funding agency for innovation, had a dominant position in developing R&D programmes and in evaluating research applications. The bureaucratic procedures were typically protracted and the gaps between evaluators and 'real life' tended to produce too little value added. The government reacted to the discontent by publishing a National Research Strategy in 2006. Recognizing new innovation trends, the National Strategy encouraged open and participative working methods. It reflected the belief that cooperation, knowledge sharing, and the willingness to share risks would generate a dynamic innovation community.

To promote the creation of such dynamics, the National Strategy proposed the foundation of Strategic Centres for science, technology and innovation for turning science and technology towards new solutions. The idea was to get all the partners involved to commit themselves to

innovation. In addition, the needs of users and consumers together with the companies' and research institutes' competence were to speed up the process from idea to commercialization. At the same time, the cooperative approach would spread new knowledge more widely.

Public-private innovation companies

In the forest industry, the major companies and public research institutes responded to the National Research Strategy by establishing Forest Cluster Ltd, a joint stock company owned by the participating partners, in 2007. The mission of the company, which soon changed its name to FIBIC (The Finnish Bioeconomy Cluster), was to formulate and manage research programmes for developing bio-based products. By mobilising actors from business and research in close, long-term cooperation, FIBIC committed itself to help developing *the entire wood-based bioeconomy field*.

In 2015, when FIBIC merged with CLEEN Ltd -- the public-private partnership for the clean tech industry -- extended opportunities for collaboration and co-creation were created. The merged innovation company, called CLIC Innovation Ltd, ties together 30 different companies from different industries, with 17 research institutes and universities as owners. In CLIC, like in FIBIC, the research programmes specify the objectives. The programmes facilitate interaction at all stages in the innovation process, from research to commercialization, both in open innovation settings and in company specific projects.

A bottom-up approach for developing research programmes

Another unique dimension of the FIBIC/CLIC construct is the way research programmes are developed. Recognizing that operative levels involving customers and clients are more capable of identifying needs and opportunities, the development of research programmes was transferred from Tekes to the public-private enterprises like FIBIC and CLEEN.

To design research programmes, to start with, FIBIC made use of online stakeholder forums as well as outside experts for developing new research programmes. A management group with representatives from both industry and academia carried out the supervision of the progress of the programmes, with respect to the objectives of FIBIC. The programmes for which potential participants had to make project proposals and compete thus brought together companies, their potential customers, end-users for products and researchers in long-term collaborative projects. The programmes' overall goal is to improve the competitiveness of the

whole wood-based bioeconomy by developing and demonstrating new types of products and technologies for expanding the potential of the wood-based product portfolio.

After the FIBIC/CLEEN merger, the development of new research programmes has been decentralized even further. For the research programme called New Fiber Development, the process started with a kick-off event that was open to any company. At the kick-off event, participants got an understanding of the objectives and guidelines for the second stage. At the second stage, sixty-five companies presented their pitch about their competences and their potential contribution. At the third stage, a number of the small companies were chosen to concept workshops for elaborating the content of the research programme. The steering group thus identified companies having relevant contributions to different subthemes. At the final stage, the steering group accepted the research programme draft. The open research part was divided into four work packages, in which both large and small companies as well as researchers from universities and research institutes participate. The government, through Tekes, financially supports all the FIBIC and CLIC programmes, providing sixty per cent of their budgets.

An open and decentralized innovation system: towards new roles

By encouraging the establishment of public-private partnerships for innovation, the government pushed the forest industry companies in the direction of open innovation. Their transition from pursuing incremental innovation, organized as a hierarchal and isolated process, to close collaboration with wide scope of actors has enabled technological breakthroughs and radical innovation. It has speeded up the innovation process, and provided the companies with competences to evaluate new ideas and opportunities. As Stora Enso commented, it gave 'a clear understanding of real-life challenges' (FIBIC, 2013). Moreover, by cooperating, companies and institutions not only share knowledge and ideas, they also share risks. Co-funding has also produced a strong commitment to the programmes.

Decentralizing the funding and organizing of innovation has resulted in a division of responsibility between the national level, defining the needs, and the operator level, preparing and implementing the activities. Also the universities and the research institutes realized this need for cross-disciplinary knowledge concentration and restructured their organizations accordingly. However, realizing that the flow of ideas, competences, technology etc. is neither restricted to the local nor the national level, the collaborative research programmes function as gateways to international cooperation. Global connectivity is imperative for being

taken seriously in the emerging bioeconomy, and both companies and research institutes have an extensive international engagement. For example, UPM, Stora Enso and Metsä Group, along with other companies and research institutes and universities, have cooperated with foreign partners in a large number of research programmes, such as foam forming, fibre-based products for new applications, and micro-cellulose. Linkages to globally innovative ecosystems and transnational epistemic communities represent an extension to the national innovation system.

Companies' and research institutes' participation in co-creation processes has required new types of action and a new role in the emerging wood-based bioeconomy. Although there is a strong tradition for cooperation in the Finnish forest sector, the new public-partnership operations represent a major change. The cooperative form appears similar to the previous one, but its institutional practice is different, due to the fact that it is extended to lower actor levels. To substantiate this claim the next section will provide a set of illustrative examples.

5 Taking on the orchestrator role

To expound the new role of the large forest industry companies and the largest research institute, the section focuses on what we term the orchestrator role (Wallin, 2006, Dhanaraj and Parkhe, 2006)). This role is related to different business logics, and the modes of interaction and activities vary accordingly. Basically, these activities revolve around mobilizing and combining different types of players: for creating new value constellations for new types of businesses; for creating mill site specific business ecosystems; and for supporting start-ups. The different organizational and institutional actors studied are more or less involved in all these activities, but for the overview, only one type of activity per actor is presented in the examples below.

Bio-diesel, a new value constellation: from public regulators to customer involvement

In 2016, UPM started full-scale production of BioVerno, the first wood-based biodiesel product in the world. In comparison with fossil fuels, BioVerno has 80 per cent less CO₂ emissions. The regulation of the fuel market for increasing the use of renewable energy prompted UPM to develop biofuel. The EU Directive for biofuel in 2003 set a 10 per cent requirement for biofuel in gasoline and diesel (Directive 2003/30/EC). The Directive for Renewable Energy in 2009, encouraging the use of forest resources, further supported UPM's

work on the new wood-based biofuel. The Finnish government's intervention -- by setting the target for the share of biofuels to be twenty per cent by 2020 -- further ensured the existence of a market, as well as reducing the risk linked with developing a radically new product.

BioVerno is made from crude tall oil, a residue from pulp production, but the technology is sophisticated and to develop it the company had to recruit external expertise as well as make use of VTT's services. The development process is typically described as being iterative, i.e. by learning from mistakes and by getting feedback from potential customers (Nousiainen, 2015). The latter has been particularly important for launching the new product, despite being 'ensured' a market. UPM had Volkswagen test it for a year, and also a bus service company in the Helsinki region to test it on heavy-duty vehicles. By involving these actors in the value constellation, UPM has been able to link customers' competences and needs to the development of the product.

BioVerno is not only distributed as a necessary component in fuel, but is carefully marketed as a 'story' with the help of the fuel retailer ST1, a Finland based company that has a goal to reduce the share of fossil fuel as a business model. Together UPM and ST1 developed a marketing plan stressing high quality, Finnishness, sustainability and continued action to reduce CO₂ emissions (Tuomaala, 2015). BioVerno's qualities provide an edge for participant actors in the value constellation, from regulators to distributors as well as owners of cars and heavy vehicles run on diesel.

Wood-based construction materials: cooperation and learning along the whole value chain

One of Stora Enso's new wood products is wood-based construction materials: cross-laminated timber (CLT) and laminated veneer lumber (LVL). As these materials can be used to construct multi-storey houses, the market is highly promising, not least because of their environmental impact. Wood-based materials are renewable, energy efficient, carbon neutral, and store CO₂. The structural elements contain CO₂ as long as the buildings are in use. In comparison with concrete they are more fire-resistant, and even stronger than steel. As the structural elements can be prefabricated, for builders, the use of wood-based construction systems can be up to 50-70 per cent more time efficient at the site compared with construction based on traditional concrete elements (Kairi, 2005, p.3; Stora Enso, 2014).

Introducing a new product requires the interaction of a wide scope of actors. Before marketing, certification from regulatory authorities is essential and is typically a protracted

process. The company, together with the industry and its associations, has spent countless hours explaining wood-based construction materials' advantages, a procedure that has had to be repeated country by country.

As the structural elements only form one part in the new construction concept, and since the market is new, Stora Enso has taken steps to have the complete value chain activated. To fill the first gap in the chain, it builds an LVL factory to secure the availability of these elements. In order to have the next stage in the chain, the production of modules, in operation, Stora Enso has supported a company specialized in this activity. Mobilizing new actors has, at the same time, involved learning processes by having the sub-suppliers fit properly into the chain.

To boost 'the construction revolution', Stora Enso is continuously in dialogue with building companies, their sub-contractors, and professional service operators to persuade them to use all kinds of wood products. To facilitate the use of wood, Stora Enso also provides software that turns designs into visual prototypes. In addition, the company has devoted considerable resources to a novel project in Helsinki. Together with a construction company, it facilitates the building of the so-called Wood City. The project comprises residential buildings, offices, and a hotel for demonstrating the advantages of wood-based buildings and interior materials. To benefit from feedback regarding customers' needs, end-users from different backgrounds and life experiences have been involved in designing space and services for helping people to smoothly combine work, family life, and spare time (Wood City, 2013). As in the BioVerno case, a wide constellation of actors has been mobilized, not only for producing and marketing a new product, but for improving the living environment and the quality of life.

Äänekoski biorefinery: a platform for multiple products

At Äänekoski, mid-Finland, the Metsä Group is building a biorefinery. The aim is to use the new mill as a platform for a wide scope of business operations and new products. As the Group itself does not prefer to make use of every bit and piece of the wood resources and of all side streams, a key task is to develop an ecosystem of companies by mobilizing other players. The Group itself produces turpentine and tall oil in addition to pulp and board. Further products to be produced from side streams are gas from bark, a waste product, which will be used as fuel for the production of chemicals. It is on the agenda to produce sulphuric acid from gas to be used in the manufacturing of tall oil and chloric dioxide. Other waste

materials and side streams will also be turned into different forms of energy, like electricity and steam (Lilja and Loukola-Ruskeeniemi, 2017, pp.20-23).

Besides the Group's own operations, it sells heat, produced from a side stream, black liquor, to the local community. To Valio, the leading milk-based-product producer in Finland, it provides heat for Valio's cheese factory. To C. P. Kelco, a division of a US based multinational, the Group has sold a spin-off operation producing carboxyl methylcellulose (CMC) at the mill site. For further product development, this relationship is important, as C.P. Kelco is the world's leading producer of CMC, an additive which can be used as a thickener, stabilizer or dispersant in products as diverse as toothpaste and oil drilling. Other arrangements include an agreement with the biogas manufacturer, EcoEnergy SF Ltd., for producing biogas from sludge from pulp production, and an agreement with the biocomposite producer, Aqvacomp Ltd., for producing a biocomposite material made from pulp fibre and plastic to be used in the electronic and car industries.

Further, another potential product is wood-based textiles, an innovation resulting from one of the collaborative research projects. To realize this, the Group is linked with Itochu Corporation, the leading Japanese general trading company for textiles. The latter has acquired an ownership stake in Metsä Fibre Ltd, the main operator of the bio-refinery.

VTT: integrating the market into research and development

VTT Technical Research Centre of Finland has been a key institution for providing research services to the national business system. Its impact has mostly been found in the form of contract research. The turn to open innovation in which companies search for the best solution globally has challenged its traditional role. VTT has itself become part of global competition, as 'Firms go to the best service provider globally'. To survive, it has to be an attractive partner and to offer the best technologies and services globally.

As radical innovation requires not only cross-disciplinary competences, its internal organization structure, based on 'silos of expertise', was challenged as well. One move was to form a strategic partnership with Aalto University that provided a cross-disciplinary knowledge platform for joint research projects to help produce innovative solutions. Joint research projects in the form of inter-disciplinary teamwork at both the national and international level are crucial for inventions.

Realizing that succeeding with innovation requires participation in all stages of the innovation pipeline – from idea to commercialization – its mode of operation has changed. Without being capable of attracting potential customers to the R&D projects at the conceptual stage, innovation and commercialisation are not likely to occur. Therefore, one of VTT's concerns is to create more value from parts of its patents and its concept innovation portfolio. Ideas for spin-offs and start-ups can arise from collaborative development work with customers. Concept projects can be shared with a client, licensed, or given as support for a start-up. As one actor phrased it, 'VTT made it possible', implying that the cooperation between the institution (VTT) and the company (the start-up) had facilitated and made possible the establishment of a new business. For facilitating the management of intellectual property rights and for commercializing products and services, VTT also changed its legal status, and established itself as a limited liability company in 2015. The new legal status rendered it autonomy to fund its own basic research by selling both IPRs and innovation services.

This type of commercial activity also involves encouraging their own employees to make use of their ideas. If judged to have potential, researchers can get funding for market research if they are interested in establishing their own company. If a start-up is based on VTT's IPRs, VTT Ventures Ltd can switch the IPR into equity and become a shareholder. One such start-up is Paptic Ltd, founded by three VTT experts. The EU's coming directive for limiting the use of plastic bags inspired the experts to explore the market for distinct types of paper bags. Recognizing that there was a potential market, deals were negotiated with customers. For facilitating the founding, VTT transferred its IPR in exchange for an ownership stake. Another spin-off example is Spinnova Ltd. piloting a new technology to spin yarn from wood fibres.

Thus, by responding to a changing environment, VTT has transformed itself from being a service provider for the national industry to become a commercial player in its own right at the international level.

6 Discussion and conclusion

For the time being, Finland is among those countries that are leading the shift to a sustainable bioeconomy. The article's objective has been to reveal and conceptualize the critical

mechanisms for her achievement in the wood-based bioeconomy. The analysis has revealed that the transformation from being a traditional forest industry with a world-class reputation in pulp and paper to becoming a frontrunner in the emerging bioeconomy has implied fundamental changes at different levels.

Empirically, the article has focused on the three largest forest industry companies and the largest research institute. Both the companies and the institute have radically changed their role. For the companies this change involves the transformation from being global players in few value chains acting in an isolated manner to becoming orchestrators of complex value constellations and ecosystems. For the research institute, it involves the transformation from being a national service provider to that of a global commercial actor. However, for both types of actors, this inter-related transformation forms part of their respective roles crucial for developing the wood-based bioeconomy.

As evidenced, this role transformation results from participating in collaborative innovation projects and processes of co-creation. For radical innovation, open innovation modes allow the mobilization of cross-disciplinary knowledge and competences needed for developing new products and businesses. An important finding is that these processes have been successful due to the fact that key players have engaged in new types of activities and changed their role. An institutional invention, involving public-private partnership companies for innovation, has facilitated this changeover. The national management strategy for innovation was accordingly altered from being typically bureaucratically operated to being decentralized to the 'real actor' level for pursuing an experimental approach.

To support the conceptualization of the critical mechanism explaining the emergence of the wood-based bioeconomy, the article has made use of actor-centred institutionalism. It claims that the way actors and institutions have changed, i. e. by learning from each other in collaborative processes, new complementarities have evolved. At all levels, actors have changed their role so it fits that of the others. This type of adjustment process implies a dynamic nature of complementarities. Thus, the case of the wood-based bioeconomy in Finland does not support views emphasizing path-dependency attributed to institutional complementarities. On the contrary, as previously shown, they can be important for mobilizing people and resources necessary for reorienting the society and the economy (Moen and Lilja, 2005).

Finland, being a typical coordinated market economy with strong cross-sectoral cooperation, may also provide an explanation for why the forest industry and related national level institutions have been able to make this transformation. It can also explain why the large companies could change from acting as solitary global players to assuming responsibility for the whole wood-based bioeconomy. Integrating sustainability into their business models, they have re-evoked their capacity for cross-sectoral cooperation. That complementarities constitute a key mechanism in an emergent industrial field suggests that studies of institutional change should take this type of phenomenon into consideration, particularly when actors and institutions are exposed to rapid changes in the environment.

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Table 1 Organizations and number of specialists interviewed

Organizations included in the study	Number of specialists interviewed
Stora Enso	3
UPM	4
Metsä Group	2
VTT	5
Forest Cluster, FIBIC, CLIC	2
Start-ups and spin-offs	4
University professors	5