# *Assessing convergence processes at the intersection of the food and pharmaceutical industries in functional food innovation using different perspectives*

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# 1 Introduction

# 1 Introduction

Due to increasing health care costs (Ziebarth, 2011) and a growing interest among consumers in products that may alleviate the symptoms of ageing and illness (Gray et al., 2003, Siró et al., 2008), the market of foods and food ingredients has changed rapidly in recent years (Siró et al., 2008). New products in the food area focus mainly on borderline products containing functional ingredients, such as probiotics or phytosterols (ref. to 1.2.2 for a description of the functional food area). This has led to worldwide growth of the functional food market in the last decades (Menrad, 2003, Sloan, 2014, Ares et al., 2008a, Ding et al., 2015). This inter-industry segment of functional foods arises at the intersection of the food and pharmaceutical industries, exhibiting an on-going process of convergence of blurring industrial boundaries (ref. to 1.2 for the definition of convergence and Curran et al., 2010, Hacklin, 2008, Bröring, 2005). On the one hand, this emerging segment offers a plethora of innovation opportunities. On the other hand, companies focusing on this emerging segment have to employ knowledge and technologies outside of their traditional expertise. Nevertheless, innovation is crucial for companies to grow and stay competitive (Rudder et al., 2001). There is, however, a low rate of innovation in the food sector compared to other industry sectors (Morgan et al., 2003), such as for instance the research-intensive pharmaceutical sector (Howells et al., 2008).

The food sector delivers products for the traditional diet, leading to functional foods or, as a further step, to dietary supplements (Eussen et al., 2011). The research and development activities in the food industry are undersized because of conservative consumers and a mature market, although research and development is known to be a key driver for a successful firm performance (Mark-Herbert, 2004). Besides the challenges related to the different involved sectors, the market orientation for successful product innovations must also be considered (Batterink et al., 2006), as these products focus on the general consumer demand for healthy products (Sloan, 2014). In contrast, pharmaceutical companies focus on the research and development of drugs, which neighbouring products are dietary supplements (Eussen et al., 2011). While focusing on scientific understanding, pharmaceutical companies lack a consumer market understanding (Bröring, 2005).

As the borderline products of functional foods and dietary supplements incorporate the nutritional and the health benefits (Spence, 2006, Hasler, 2002), their development needs the competences from both the food and the pharmaceutical sectors. Therefore, the innovation process must address the upcoming challenges according to different industrial competences, leading to industry convergence where technical and regulatory boundaries between sectors of the economy blur (OECD, 1992). The dynamic characteristics of converging industries determine the innovation process as new areas of technology, market and regulation become relevant for innovation (ref. to 1.2.1. for a description of the innovation process in converging industries).

## 1.1 Challenges to be addressed

As the dynamic characteristics of converging industries determine the innovation process, drivers and barriers to functional food innovation can be identified. On the one hand, critical success factors of food innovation are market orientation (Batterink et al., 2006) as well as customer orientation (Fortuin et al., 2007). On the other hand, main barriers of this industry are considered to be insufficient innovation competencies (Batterink et al., 2006, Garcia Martinez and Brizb, 2000) or the inefficient employment of consumer-oriented food development due to the lack of concrete guidelines (Costa and Jongen, 2006). Regarding the rapid changes of the functional food market, firms active in this inter-industry segment face exceeding challenges within the innovation process. These challenges are related to the upcoming legislation (Bech-Larsen and Scholderer, 2007), changes in the market (Mark-Herbert, 2004) and the consumer awareness and acceptance (Verbeke, 2005). The studies regarding the food or functional food market mainly consider companies from the traditional food sector (e.g.

Mark-Herbert, 2004). However, in the case of functional foods identified as a convergence area between foods and drugs, the pharmaceutical sector is active in the functional food market as well (Curran et al., 2010, Bröring, 2005).

Because of high failure rates, the improvement of the food innovation process is crucial in order to create successful market launches of borderline products in converging industries (Stewart-Knox and Mitchell, 2003). There is a constant flow of new product launches in the functional food sector; this is in contrast to established food markets, where most new products are only variations of existing products (Mark-Herbert, 2004). However, only a few of the new functional food products become successful (Stewart-Knox and Mitchell, 2003, Costa and Jongen, 2006, Bogue and Sorenson, 2009, Sparke and Menrad, 2009). To improve cross-industry innovation in converging industries, cross-industry relationships should be considered in order to derive a new innovation process model (Gassmann et al., 2011).

It is important to have an efficient and structured innovation process (Man et al., 2010), which is one of the core competencies of a firm (Brown and Eisenhardt, 1995). The emphasis on the innovation process becomes especially important in converging areas, in which innovations lead to new inter-industry segments (Hacklin et al., 2009). Thus, the comparative perspective on the innovation and convergence process delivers a framework to analyse innovation processes in converging industries. As the involved companies from different industrial backgrounds will differ when faced with the related innovation challenges, this thesis will focus on the assessment of the convergence process from different perspectives.

The overall aim of this thesis is to evaluate the convergence process between the food and pharmaceutical industries in the area of functional foods using different perspectives. These perspectives are based on the conceptualisation of the innovation process in converging industries to deliver a holistic view of the complete convergence process. Since former literature focuses on the front end of the convergence process, this study enhances the existent literature by including the neglected steps of market and industry convergence. Research perspectives are delivered that have not previously been applied to the theory of convergence. Furthermore, as the challenges of convergence are widely discussed in the technologically driven areas such as information and communication technology (ICT) (e.g. Hacklin, 2008, Katz, 1996), this study enhances convergence literature by delivering an in-depth example of functional foods emerging between the food and pharmaceutical industries. Therefore, the present thesis aims

- **to evaluate the convergence process using different perspectives in order to derive an assessment framework of the innovation process in converging industries.**

Based on the main objective of this thesis, the following set of research questions (ref. Figure 1-1) can be derived that focus on the integration of the different perspectives. Next to the integration of the different perspectives (main research question), one research question addresses the academic context while focusing on the extension of already existing convergence assessment approaches. Furthermore, one research question concentrates on the integration of the different perspectives into the innovation management process, especially in the food and pharmaceutical industries, delivering an applied context (ref. Figure 1-1).

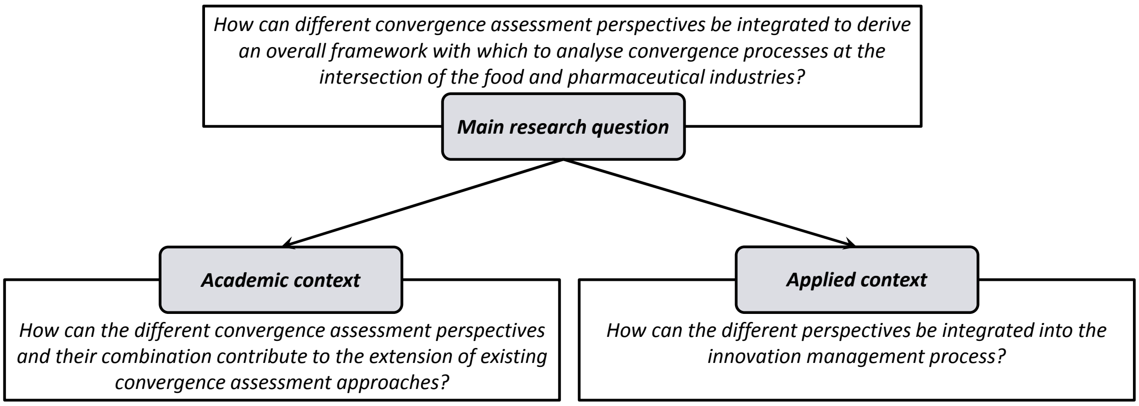


*Figure 1-1: Overview of overall research questions*

The structure of this introduction chapter is as follows. The next section (1.2) focuses on the convergence process, and challenges of innovation for the emerging sector of functional foods are addressed. The following part (1.3) delivers the different theoretical perspectives, which are applied in the consecutive part (1.4) to the empirical studies. This chapter concludes with an outline of the thesis.

## 1.2 Convergence process

Multifaceted definitions of the convergence phenomenon can be found in recent literature (e.g. Kim et al., 2015, Curran et al., 2010, Hacklin, 2008). In many studies, the convergence concept is primarily associated with technology convergence, as the general idea of convergence goes back to the overlapping of technologies (Rosenberg, 1976, Stieglitz, 2002). However, convergence is a multifaceted phenomenon that should not be reduced to the technological level (Borés et al., 2003, Nyström, 2008). Several studies provide a comprehensive overview of convergence definitions and their different emphases (Bröring, 2005, Curran, 2010, Hacklin, 2008, Preschitschek, 2014), mainly following the common idea summarised by the Organisation for Economic Co-operation and Development as follows: *'the blurring of technical and regulatory boundaries between sectors of the economy'* (OECD, 1992).

The literature discusses the concept of converging industries as a process rather than a steady state (Curran et al., 2010, Hacklin, 2008). The convergence process is considered to follow the consecutive steps of science, technology and market convergence, leading to a complete industry convergence where companies or whole industry segments fuse (Curran et al., 2010, Hacklin, 2008), ref. Figure 1-2. Thus, the consecutive steps follow an idealised time series, leading to a complete convergence of formerly distinct industry segments. Science convergence as the first step in this time series implies that distinct scientific disciplines begin to cite each other (Curran et al., 2010). Furthermore, the initial step of convergence encompasses the first collaborations of different scientific disciplines, such as for example the collaboration of different departments of one university or different research institutions. The following step of technology convergence describes the decreasing of the distance between applied sciences and technology development. In other words, based on the merging of basic science areas, applied science and thus technology development follows (Curran et al., 2010, Meyer, 2000). The subsequent step of market convergence entails the occurrence of new product-market combinations. Finally, the last step of industry convergence incorporates fusion of firms or industry segments (Curran et al., 2010). Most literature sources (Preschitschek, 2014, Kim et al., 2015, Bröring et al., 2006) use the term '*industry convergence'* for the last phase as well as for the whole phenomenon because the last step is concurrently the result of the process. In this study, the term *'convergence'* is used for the complete process and *'industry convergence'* for the last phase of the convergence process.

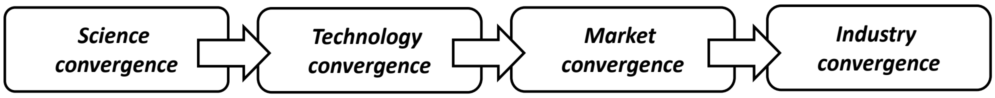


*Figure 1-2: Convergence process (based on Hacklin, 2008, Curran et al., 2010)*

### 1.2.1 The innovation process in converging industries

Innovation is a multidimensional construct that covers the invention itself as well as its commercial exploitation (Hauschildt and Salomo, 2014). Dimensions of innovation could be summarised as the introduction of new products, the application of new materials leading to the commercialisation of new combinations, the introduction of new processes, the opening of new markets, or the introduction of new organisational forms (Schumpeter, 1934, Fortuin and Omta, 2009, Tepic et al., 2009). Based on this broad definition of innovation as the commercial introduction of new ideas, the innovation process refers to the implementation of innovation as a sequence of events that occur during the interaction between actors in order to develop and implement their innovation ideas within an institutional context (VanDeVen, 2000).

In former literature, different models of the innovation process are described, leading to a large number of different approaches (Poole and vanDeVen, 2000); for instance portfolio management (Cooper et al., 2001), a cycle of innovation (Jones and Jew, 2007), Quality Function Deployment (QFD) (Costa et al., 2001, De Pelsmaeker et al., 2015), or the Stage-Gate® system (Cooper, 2001). These innovation process models are not industry-specific as they provide general approaches. All of these schemes structure the innovation process into several stages of special issues. Thus, the basic progression of activities over the course of the process is similar (Veryzer, 1998). The innovation process incorporates several stages, considering commercial, academic and regulatory interests, with a critical need to achieve consumer acceptance (Jones and Jew, 2007). Therefore, the multifaceted intentions as well as the different objectives justify the various accepted innovation process models (Hahn, 2015). In summary, four main phases can be identified, showing a simplified innovation process: (1) idea generation and selection, (2) development, (3) product testing, and (4) market launch to consumers.[1]

Linking these steps to the convergence process, first the step of science convergence, in which distinct scientific disciplines begin to cite each other and collaborate, covers the first phase of idea generation and selection in the innovation process. In this phase of idea screening, the strategic fit, market attractiveness and the technical feasibility all play important roles (Cooper, 2001). Furthermore, the preliminary assessment of market and technical feasibility is based on on-going scientific discussion that can be found in scientific publications. In the case of converging industries, science from in- and outside one's own industry sector must be included, which may result in citations of neighbouring sectors as well as collaborative scientific articles. As scientific evidence is needed within the development, science convergence might endure into the early development phase of the innovation process. In this early phase, there may be an overlapping of science and technology convergence as technology convergence includes the decreasing of the distance between applied sciences and technology development (Hacklin, 2008, Curran et al., 2010). Market convergence in which new product-market combinations occur (Bröring, 2005, Preschitschek, 2014) corresponds to the product

[1] For an extensive discussion about the different developments of innovation process models as well as the differences in the number of phases, please refer for instance to the overview given by Hahn (2015), p. 19ff.

testing and market launch in the innovation process. The consecutive fusion of firms or industry segments is called industry convergence (ref. Figure 1-3).

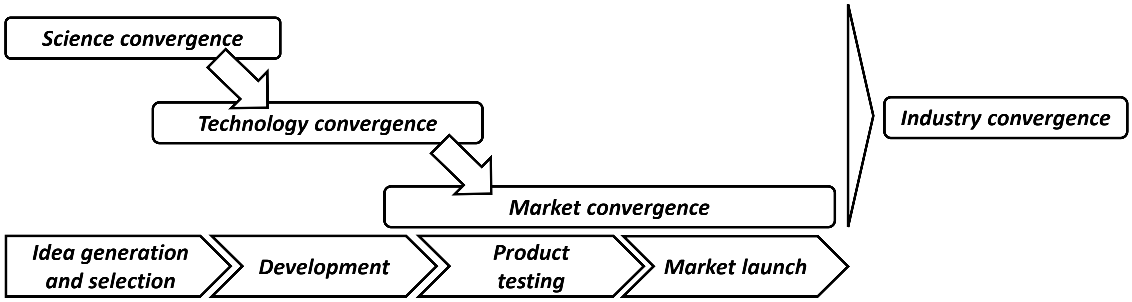


*Figure 1-3: Comparative perspective on the innovation and convergence processes*

### 1.2.2 The area of functional foods

Major issues in public health such as obesity, cardiovascular diseases, age-related cognitive decline, metabolic syndrome, insulin resistance and diabetes (Green and van der Ouderaa, 2003) have led to increasing health care costs over the last decades in most industrialised countries (Ziebarth, 2011). Several of these diseases and dysfunctions are thought to be related to nutrition. For example, as obesity is mainly caused by excess energy intake and reduced energy expenditure (Uchiyama et al., 2011), it can be tackled through exercise or dietary changes. Different functional ingredients, which are present as value-adding components in functional foods, are supposed to have a positive effect on the metabolism, and thus on obesity (e.g. black tea polyphenols, ref. Uchiyama et al., 2011). Next to the scientific research on the possible health benefits of functional foods, consumers' perception of foods has changed from satisfying hunger and providing necessary ingredients to preventing nutrition-related diseases and improving physical and mental well-being (Menrad, 2003, Roberfroid, 2000a, Bigliardi and Galati, 2013). This has led to a growing consumer interest in food products that may alleviate the symptoms of ageing and illness (Annunziata and Vecchio, 2011, Gray et al., 2003, Siró et al., 2008, Wong et al., 2015).

Although a legal definition of functional foods is still missing, the literature about this phenomenon summarises functional foods as delivering a health benefit beyond nutritional value (e.g. Spence, 2006, Siró et al., 2008, Kloosterman et al., 2007, Hasler, 2002). Therefore, functional foods aim to prevent deficiency diseases and chronic diseases (Kloosterman et al., 2007). In other words, functional foods shall improve for instance on the one hand general conditions of the body or on the other hand disease related functions such as reducing the risk or even curing of some illnesses (Mark-Herbert, 2004, Menrad, 2003, Bigliardi and Galati, 2013). To fulfil these needs, the category of functional foods encompasses fortified foods with an increased content of nutrients, enriched foods with added nutrients, altered products with certain nutrients replaced by more beneficial components, and enhanced commodities with an altered nutrient composition in the raw commodities (Spence, 2006). Obviously, these categories of functional foods focus on the inherent ingredients, which are supposed to deliver a special health benefit to the consumer. **This study deals with the functional food sector emerging between the food and pharmaceutical industries while using certain functional ingredients as a measure in the following studies.**

Next to functional foods, there is a wide range of borderline products emerging between the food and pharmaceutical industries that contain the same functional ingredients as those inherent in functional foods (Eussen et al., 2011). As the most prominent categories beside functional foods, dietary supplements and medical foods are presented as exemplary. Dietary supplements entail a drug-like appearance, as they are sold in the form of pills, powder or liquid (Kaur and Das, 2011). Although the intake of dietary supplements covers a substantial proportion of the vitamin and mineral intake (Rock, 2007), they are not aimed to replace a normal diet (Kaur and Das, 2011, Georgiou et al., 2011) in contrast to most functional food products. Medical foods aim for the prevention and treatment of malnutrition related disorders while delivering a nutritionally complete food (Georgiou et al., 2011, Weenen et al., 2013a).

Especially in the last decades, many different functional ingredients have emerged on the functional food market (Ares et al., 2008a, Siró et al., 2008), while the growth trend of this market segment is still on-going (Ding et al., 2015, Sloan, 2014). Worldwide leading products are vitamins and minerals next to combination supplements (Euromonitor, 2012). Vitamins and minerals as functional food ingredients are well known among a wide range of consumers (Hoefkens et al., 2011), possibly due to the fact that they are the most common type of dietary supplements (Rock, 2007) and are based on substantiated scientific evidence. Next to these products containing functional ingredients with a long research history, there are also more recently described functional food ingredients that are claimed to be beneficial for nutritional and health aspects, such as probiotics and phytosterols (Verhagen et al., 2010). The novelty of the ingredients might promise market success despite the challenges of new product development (Herath et al., 2008, Bech-Larsen and Scholderer, 2007), which may trigger new product launches (Verhagen et al., 2010).

Prominent examples of successful functional food products are phytosterol-enriched margarines (e.g. Benecol®, Becel pro.activ™ on the European market) or the daily-dose drinks enriched with probiotics in small bottles (e.g. Danone's Actimel or Yakult), which is one of the most successful categories in functional foods (Annunziata and Vecchio, 2013, Saxelin et al., 2005). Although the functional food market is growing worldwide (Siró et al., 2008), there are cross-cultural differences between consumer acceptance of the available functional foods leading to the necessity of market segmentation (Frewer et al., 2003, Labrecque et al., 2006, De Jong et al., 2003, Saulais et al., 2012). Besides the cross-cultural differences, consumer acceptance is dependent on the type of the functional food (De Jong et al., 2003); therefore a general market segmentation to identify general consumer characteristics is hardly possible (De Jong et al., 2003). Nevertheless, the general belief in the health benefits seems to be a superordinate indicator in consumers' acceptance of functional foods (Verbeke, 2005). In addition, as consumers are not willing to compromise taste for health (Verbeke, 2006, Tuorila and Cardello, 2002), the general success factor for the marketing of foods – *'taste'* – determines the success of functional foods as well (Menrad, 2003).

The elaboration of the innovation process in general is a traditional field of research within business management, whereas the detailed description of new industry segments can only be as young as the product category itself. The first description of the functional food category was promoted in 1984 by Japanese scientists (Siró et al., 2008). Approximately two decades later the first publications emerged about the functional food innovation process (see for instance Mark-Herbert, 2004, Jones and Jew, 2007).

Summarising the models of the food innovation process, the product category of foods entails specific challenges during the innovation process, which have to be considered in the specific environment of functional food innovation. Due to the complexity of food products based on the inherent (functional) ingredients, higher standard deviations in ingredient compositions might occur, leading to large differences in the final product (Benner et al., 2003). In turn, these changes must be considered during the innovation process, leading to a model that allows flexibility. Besides the complexity of food composition, the product development of food products should consider sensory aspects (Rudder et al., 2001). As the taste shows great impact on consumers' food choices (Verbeke, 2006, Tuorila and Cardello, 2002), the fortification of functional foods with functional ingredients may negatively affect the sensory product characteristics: for instance, omega-3-fatty acids may cause a *'fishy'* off-note.

Moreover, the process impacts the final product (Benner et al., 2003). Particularly because food products are fast moving consumer goods, the consumer and market orientation in food products and therefore in their development process is of importance. The major trend of health and well-being determines the innovation process of food products and has led to a plethora of functional food products delivering a health benefit beyond their nutritional value (see for instance Menrad, 2003, Bigliardi and Galati, 2013, Roberfroid, 2000b). Whereas the food market is characterised as a saturated market (Stockmeyer, 2002) delivering commodities, the complexity of products increases when moving towards functional foods. Due to this increasing complexity, these borderline products require explanation (Stockmeyer, 2002).

Specific challenges are related to the functional food innovation process besides the traditional food innovation.[2] Efficacy, safety and evidence are essential for the development of a new functional food, because only with the confirmation of a substantiated health effect can a health claim be made about the product (Jones and Jew, 2007). Health claims to communicate the additional benefit to the public are needed to qualify consumers' awareness and knowledge. Within a higher consumer awareness and knowledge, the consumer acceptance increases and leads to industry growth (Jones and Jew, 2007).

A new value chain between the traditional sectors of food and pharmaceutics emerges and leads to the inter-industry segment of functional foods, while the traditional value chains of the food and pharmaceutical sectors remain (Bröring and Cloutier, 2008). Buyer-seller relationships along value chains become central to value creation (Bröring and Cloutier, 2008, Omta, 2004, Wirtz, 2001), as firms increasingly concentrate on core competences (Lindgreen and Wynstra, 2005, Bröring and Cloutier, 2008). The need for the competences of the different industry sectors might lead to competence gaps of the involved firms (Pennings and Puranam, 2001). The stretch of resources to serve the adjacent industry, resp. emerging inter-industry segment might result in competence gaps (Pennings and Puranam, 2001). In other words, the core competences of one sector will appear as competence gaps of the other sector, while the research and market areas of these two sectors converge. Companies' strategic actions to close the arisen competence gaps encompass the internalisation of external assets, for instance through the acquisition of companies or strategic alliances (Bower, 2001, Gambardella and Torrisi, 1998), and thus different forms of collaborations.

The following table summarises the above-described characteristics of the functional food innovation process based on food product development (ref. Table 1-1).

[2] Recent scientific discussions stress that the complexity of the functional food innovation process is higher than the innovation process of conventional products as the functional food innovation process includes for example the characterisation of the constituent or human intervention studies (Sebök et al., 2016).

*Table 1-1: Overview of the characteristics of functional food innovation*

| Characteristics of functional food innovation | Sources of literature |
|---|---|
| Scientific background to substantiate the health effect beyond the nutritional value | Arai et al., 2001<br>Jones and Jew, 2007 |
| Complexity of food composition due to the inherent functional ingredients | Benner et al., 2003<br>Krutulyte et al., 2011 |
| Emergence of new value chains between the food and pharmaceutical sectors | Wirtz, 2001<br>Omta, 2004<br>Bröring and Cloutier, 2008 |
| Competence gaps between the food and pharmaceutical sectors | Bröring, 2005<br>Curran, 2010 |
| Emergence of health claim regulation | Herath et al., 2008<br>Hermann, 2009 |
| Consumer acceptance of health claims | Leathwood et al., 2007<br>Van Trijp and Van der Lans, 2007<br>Lalor et al., 2011 |
| Sensory aspects (for instance affected by the fortification with functional ingredients) | Roininen and Tuorila, 1999<br>Rudder et al., 2001<br>Urala and Lähteenmäki, 2003<br>Ares et al., 2008b |
| Consumer awareness of health effect (consumer acceptance) | Bech-Larsen et al., 2001<br>Saulais et al., 2012<br>Carrillo et al., 2012<br>Grunert et al., 2012 |
| Trend of health and well-being | Roberfroid, 2000b<br>Menrad, 2003<br>Bigliardi and Galati, 2013 |

## 1.3 Theoretical perspectives

The characteristics of the innovation process in functional foods determine the emerging area between the food and pharmaceutical sectors, while companies of a food or pharmaceutical background meet the upcoming challenges differently. The present thesis aims to deliver a framework with which to assess convergence from different perspectives during the complete convergence process. In the following section, the theoretical perspectives and their measures used in the present thesis are related to the different steps in the convergence process.

### 1.3.1 Life cycle perspective

Converging industries are based on market changes that can be reflected by life cycle concepts (e.g., Herrmann, 2010, Höft, 1992). Life cycle theories originate in biology and reflect the life cycles of living beings (e.g. Herrmann, 2010, Faßbender-Wynands and Beuermann, 2001). Based on these deliberations, one general definition of life cycles is as follows: *'a progression through a series of differing stages of development'* (Farlex, 2014). In marketing research, these stages are commonly defined as introduction, growth, maturity and decline (Höft, 1992, Herrmann, 2010).

Specialised concepts that focus on one certain area of life cycle concepts are described in the literature. For instance, the product generation life cycle extends the product life cycle to the description of *'the time span between the time that the first product of a product generation is delivered to the customer and the time when the total volume of the production of this product is just 10 % of its maximum'* (Fortuin, 2007). As another example of a specialised life cycle concept, the technology life cycle delivers an approach to measure technological changes (Gao et al., 2013, Haupt et al., 2007). In former literature, technology life cycles are often combined with an analysis of patent data (Gao et al., 2013, Taylor and Taylor, 2012) leading to a patent life cycle that is based on the *s*-curve concept of technologies (Ernst, 1997, Haupt et al., 2007). Because the attractiveness of different markets influences the technology life cycle and consequently the patent life cycle (Haupt et al., 2004), different life cycles occur in distinct markets. Therefore, the concept of patent life cycle appears to be a useful measure with which to interpret results according to the phenomenon of convergence.

Relating convergence processes and life cycle concepts, one approach is to extend the patent life cycle to further bibliometric data such as scientific publications (Daim et al., 2006, Curran, 2010). Based on this extension, the first two phases are covered in recent studies based on scientific publications for science convergence and patents for technology convergence (Curran et al., 2010, Preschitschek, 2014). A time lag is postulated between the occurrence of scientific publications and patents, and thus between science and technology convergence (see for instance Curran, 2010). Watts and Porter introduce further technology life cycle indicators (Watts and Porter, 1997, Järvenpää et al., 2011). These indicators may be used to operationalise the consecutive phases of the convergence process.

As current studies concentrate on the front end of the convergence process, including science and technology convergence, to anticipate the process (Curran, 2010), the literature on the evaluation of the complete process is scarce. However, since many convergence fields, such as the ICT sector, are described in the literature published several years ago (e.g. Farber and Baran, 1977, Henderson and Clark, 1990, Katz, 1996), these processes have already reached a maturity phase. A broader perspective on the evaluation of the complete convergence process might enable researchers and practitioners alike to determine the progress of convergence processes, thus including the later phases. Chapter 2 of this thesis addresses this research gap by employing a comprehensive evaluation of the three consecutive steps of science, technology and market convergence using a life cycle perspective. Applying the life cycle indicators (Watts and Porter, 1997, Järvenpää et al., 2011) to the consecutive phases of convergence processes, this study delivers a quantitative approach. With regard to the two first phases of science and technology convergence, the study is confirmatory based on the application of scientific publications and patent documents as measurements according to former studies in other convergence fields (Curran, 2010, Preschitschek, 2014). The evaluation of the consecutive step of market convergence using product launch announcements follows an exploratory approach, as the literature in this field is limited and news reports on product launches have not yet been used to operationalise market convergence.

### 1.3.2 Innovation value chain perspective

The chain and network science perspective is of a high relevance for the structural analysis of industries and industry developments (Omta et al., 2002), and therefore of convergence processes as an on-going development in many different industry fields (Hacklin, 2008). During these processes, value chains of different industry sectors begin to overlap, leading to inter-industry segments (Bröring and Cloutier, 2008). In general, value chains are defined as '*the full range of activities which are required to bring a product or service from conception, through the different phases of production… delivery to final consumers, and final disposal after use'* (Kaplinsky and Morris, 2000). The consideration of the value chain is of high importance since the partners within the value chain are still the most important sources of knowledge applied to develop inventions (Giuri et al., 2007, Enkel and Gassmann, 2010). In the context of convergence, the partners within the value chain stem from different industries that overlap in the convergence area.

Refining the general value chain concept in terms of the innovation process, Hansen and Birkinshaw introduce the concept of the innovation value chain (Hansen and Birkinshaw, 2007). The first two phases of the innovation value chain focus on idea generation and conversion (Hansen and Birkinshaw, 2007), which correspond to the early research and development phase in general value chains. These phases encompass the discovery of new knowledge, which is then used to create new and improved products (Kaplinsky and Morris, 2000). The two first phases of the convergence process cover these phases, since the discovery of knowledge from neighbouring disciplines in scientific publications and the technology convergence with the application of a technology in patents both correspond to the idea generation and conversion (Hansen and Birkinshaw, 2007, Kaplinsky and Morris, 2000). The delivery to final consumers is encompassed by the subsequent commercialisation phase in the general value chain concept and the idea diffusion in the specialised concept of innovation value chains (Kaplinsky and Morris, 2000, Hansen and Birkinshaw, 2007). This corresponds to the step of market convergence, where new product-market combinations arise (Bröring, 2005).

Current studies using a value chain perspective in the analysis of converging processes (e.g. Bröring and Cloutier, 2008) focus on the reconfiguration of the value chains belonging to different industry sectors. However, the specialised concept of the innovation value chain (Hansen and Birkinshaw, 2007) has not yet been applied to evaluate convergence processes. Filling this research gap, Chapter 3 of this thesis aims to extend the current literature on the evaluation of convergence processes to the perspective of the innovation value chain using different indicators of convergence. These indicators correspond to the consecutive steps in convergence processes: analysing scientific publications, patent documents and cross-industry collaborations such as strategic alliances or licensing agreements. Special attention is given to the comprehensive usage of those indicators, as former literature does not deliver a comprehensive approach of these indicators. In doing so, the study follows a qualitative and exploratory approach.

### 1.3.3 Collaboration perspective

Convergence processes are based on the activity of distinct industry sectors and the companies belonging to those distinct sectors (Hacklin, 2008). In general, in innovation processes the involvement of partners in collaborations is of high importance for instance to strengthen a faster development process or to improve economies of scale (de Faria et al., 2010, Ahuja, 2000, Hagedoorn and Duysters, 2002). During convergence processes, these partners stem from different industrial backgrounds. The emergent market implies a vulnerable strategic position of the involved companies due to the difficult market situation of competitors stemming from different industry sectors. In the context of the resource-based view (RBV, originated in Penrose, 1959), this vulnerable strategic position triggers companies to join collaborations in order to obtain critical resources and competences that enable them to share costs and risks (Eisenhardt and Schoonhoven, 1996, Das and Teng, 2000, Parmigiani and Rivera-Santos, 2011).

Firms comprise a set of resources and competences that establish their knowledge and technology development (Caloghirou et al., 2004) and thus their competitive advantage (Barney, 1991). Contrary to studies in the RBV literature assuming a heterogeneity in internal resources and competences within companies of one industry (Peteraf, 1993, Barney, 1991), convergence literature discusses a high homogeneity within the sectors that then merge during the convergence process (e.g. Curran et al., 2010, Bröring, 2005, Hacklin, 2008). Although the internal resources and competences might differ between single companies, the distance between the resources and competences of different industry sectors may be even greater. A homogeneity at a higher level within an industry sector might be assumed leading to industry-specific resources (Penrose, 1959). Thus, the level of competence complementarity is lower within one industry segment while being higher between different industry sectors. One main challenge in cross-industry innovation is to find a sufficient distance, which on the one hand ensures a certain degree of newness to foster innovation but on the other hand is close enough to the company’s inherent knowledge to be adapted (Enkel and Gassmann, 2010). During convergence processes, companies from different industrial backgrounds, accordingly encompassing different resources and competences, begin to focus on the same new emerging inter-industry segment.

Recent studies address innovation from a collaboration perspective (see for instance de Faria et al., 2010). However, the application in the convergence literature is rather sparse, first showing studies using collaborations as a measure for market convergence (Preschitschek, 2014, Sick et al., 2015). Although these studies relate different types of collaborations to converging industries, there is a research gap in analysing the kinds of cross-industry collaborations from an RBV. Chapter 4 of this thesis addresses this research gap by evaluating the different kinds of cross-industry collaborations. This part of the thesis follows a qualitative exploratory approach to shed some light on the formerly neglected area of evaluating convergence from a collaboration perspective using the RBV.

### 1.3.4 Consumer perspective

One major challenge and key success factor during the innovation process of functional foods is consumer acceptance (see for instance Verbeke, 2005, Weststrate et al., 2002). Although the term *'functional food'* is commonly used, the concept is not yet universally known among consumers (Del Giudice and Pascucci, 2010). Even a legal definition is still missing in Europe (Verhagen et al., 2010).

As functional foods claim to deliver a health benefit beyond their nutritional value (Hasler, 2002), they are becoming more complex than their counterparts in the traditional food domain. While the complexity increases, companies of the involved sectors face the challenge of communicating this complex health benefit to consumers. In Europe the health claim regulation (EC No 1924/2006) dealing with nutrition and health claims administers the labelling of foods and dietary supplements with additional health benefits. It applies the principle of prohibition with the reservation of permission (EC No 1924/2006). Due to the on-going evaluation process as well as the rejection of many submitted dossiers, it is not possible to state a possible health benefit for several functional ingredients available in the market (in the case of probiotics see for instance Glanville et al., 2015). However, the knowledge of the health benefit is pivotal for consumer acceptance of a functional food (Pounis et al., 2011). The causal hierarchy of nutritional knowledge from attribute-level knowledge to knowledge of the personal consequences of consumption implies for the example of functional foods the hierarchy from ingredient knowledge to knowledge about the health effect. Hence, knowledge about a certain ingredient is the precondition for the knowledge about the health effect of this ingredient (Wansink et al., 2005), and thus for consumer acceptance of the functional food (Pounis et al., 2011, Jones and Jew, 2007).

Consumer acceptance studies in all stages of the innovation process foster the later market success of the developed product (Van Kleef et al., 2005). The literature about the integration of the consumer perspective into the innovation process in converging industries is limited while focusing on technological driven areas (Lee and Cho, 2015). However, consumer acceptance of a new convergence product is dependent on the inherent product characteristics – in the case of functional foods the functional ingredients that deliver a health benefit beyond their nutritional value. Since awareness is an important precondition for general knowledge (Peter et al., 1999), the special case of ingredient awareness is an antecedent of knowledge and therefore a precondition for consumer acceptance of functional foods.

As consumer acceptance is a key success factor for product launches (Verbeke, 2005, Weststrate et al., 2002), previous studies show a great research interest in distinct areas regarding consumer acceptance of functional foods, for instance regarding healthy food choices (Roininen and Tuorila, 1999, Urala and Lähteenmäki, 2003, Krystallis et al., 2008) or the acceptance of nutrition and health claims (Bech-Larsen and Scholderer, 2007, Van Trijp and Van der Lans, 2007, Verbeke et al., 2009, Lalor et al., 2011, Leathwood et al., 2007). However, literature about consumers' awareness of certain health ingredients is scarce. Former studies focus on general nutritional knowledge (e.g. Grunert et al., 2012, Carrillo et al., 2012, Scagliusi et al., 2009), but less is known about the awareness of functional ingredients. Chapter 5 of this thesis addresses to this research gap by evaluating consumers' ingredient awareness of ten functional ingredients to analyse the consumer perspective in the step of market and industry convergence. In addition, main determinants of ingredient awareness are identified since the acceptance of functional food ingredients is influenced for instance by the way in which consumers obtain their information (Del Giudice and Pascucci, 2010). As former studies already address the general nutritional knowledge, this part of the thesis follows a quantitative confirmatory approach while applying the general concepts to the special case of ingredient awareness.

## 1.4 Aims and outline of the thesis

The subsequent Chapters 2-5 present empirical studies focusing on the innovation process in the converging area of functional foods while using certain functional ingredients as measure. These studies are based on the above-described theoretical perspectives to assess the convergence process. The following table (ref. Table 1-2) gives an overview of the theoretical perspectives and the underlying analysis determinants. Chapters 2 and 3 consider the comprehensive analysis of convergence processes and focus on the specific ingredient category of probiotics inherent in many functional food products, while Chapters 4 and 5 focus on the in-depth analysis of advanced convergence processes using the examples of various different ingredients inherent in functional food products on the market. The following part outlines the thesis setup including the related research questions per chapter focusing on the different assessment perspectives.

*Table 1-2: Overview of study design*

| | Chapter | Theoretical perspective | Unit of analysis | Measurement | Approach |
|---|---|---|---|---|---|
| **Comprehensive analysis of convergence processes** | 2 | Life cycle perspective | Industry | Scientific publications<br>Patents<br>Reported product launches | Quantitative<br>Confirmatory & exploratory |
| | 3 | Innovation value chain perspective | Company | Scientific publications<br>Patents<br>Application of regulation<br>Cross-industry collaborations | Qualitative<br>Exploratory |
| **In-depth analysis of later convergence phases** | 4 | Collaboration perspective | Company | Cross-industry collaborations<br>Product portfolios | Qualitative<br>Exploratory |
| | 5 | Consumer perspective | Consumer | Determinants of consumers' ingredient awareness | Quantitative<br>Confirmatory |

Chapter 2 of this thesis focuses on the innovation process in converging industries evaluating science, technology and market convergence. Functional ingredients such as probiotics emerge at this borderline with a high relevance for the rapidly changing food market and the related innovations (MarketsandMarkets, 2010). Dairy products enriched with probiotics are one of the most successful functional foods in the market (Annunziata and Vecchio, 2013), especially considering the rise of the new category of daily-dose drinks in small bottles (Saxelin et al., 2005). Therefore, this part focuses on the specific ingredient category of probiotics.

Although the literature evaluating science and technology convergence relates specific life cycle concepts such as the patent life cycle to converging industries (Curran, 2010, Ernst, 1997, Weenen et al., 2013c), the literature on the general application of the life cycle concept to the context of convergence is lacking. Against this backdrop, this study addresses the evaluation of convergence processes on the level of science, technology and market using a life cycle perspective. It measures science convergence by the number of scientific publications in the area of probiotics. Patent documents focusing on probiotics are used to depict technology convergence. Market convergence is represented by the reported product launches of products containing probiotics. Furthermore, cross-industry activities in scientific publications, patents and product launches are analysed. This leads to the following two research questions focusing on life cycle patterns on the level of science, technology and market convergence:

*RQ1.1 To what extent can cross-industry activities be depicted in life cycles?*

*RQ1.2 What kinds of life cycle patterns can be identified in the convergence process?*

Differences in life cycle patterns between industries are scrutinised, adapting life cycle indicators to the involved industry sectors. Cross-industry activities, which encompass activities of different industry sectors in one scientific publication, patent or reported product launch, may appear during the convergence process occurring in science, technology and market life cycle. This part of the thesis delivers a framework with which to analyse the competitive environment, especially while identifying cross-industry activities. From an academic perspective, a research framework to analyse converging processes – especially including market convergence – is delivered explaining convergence characteristics. However, the sole consideration of bibliometric data is not adequate to describe and explain the dynamics in convergence processes regarding the intertwined relationships between the actors involved.

Thus, the second empirical study in this thesis (Chapter 3) concentrates on the assessment of convergence processes from an innovation value chain perspective. The consideration of the innovation value chain in the context of convergence is of great importance because the partners are still the most important sources of knowledge for developing inventions (Enkel and Gassmann, 2010, Giuri et al., 2007). Regarding convergence processes, these partners stem from different industrial backgrounds, leading to cross-industry relationships along the innovation value chain.

In Chapter 3 of this thesis, five different indicators are used to assess convergence processes from an innovation value chain perspective on a company level: first, cross-industry relationships along the innovation value chain; second, science convergence based on the analysis of scientific publications; third, technology convergence measured by patent documents; fourth, convergence in regulatory compliance showing activity in applying the relevant legislative texts; and fifth, competence convergence showing mergers and acquisitions, licensing agreements and strategic alliances.

In order to identify convergence, companies in the converging area of foods and drugs are analysed based on products containing the four bacteria strains *Lactobacillus caseii* DN 114001, *Bifidobacterium lactis* Bb12, *Lactobacillus acidophilus* LA5 and *Lactobacillus rhamnosus*. Hence, the commercial availability of the strains on the market serves as a selection criterion. In summary, the assessment based on these indicators is used to answer the following research question:

*RQ2 How can convergence be assessed using an innovation value chain perspective?*

A total of 12 companies stemming from four industrial backgrounds – food (5), pharmaceutics (5), chemistry (1) and personal care (1) – and one research organisation are identified. The set of indicators reflecting the intensity of convergence delivers a comprehensive approach to analysing convergences processes from an innovation value chain perspective, which has so far been neglected in the existent literature. Based on this framework, the three different strategic types of (a) technology developers, (b) technology-intense product developers, and (c) product developers using existing technologies introduced by Bröring and Cloutier (Bröring and Cloutier, 2008) can be identified in the companies analysed in this study.

The different strategic types of the companies may be due to their underlying resources and competences (Barney, 1991, Dierickx and Cool, 1989, Peteraf, 1993). A firm's competence originates in the coordinated utilisation of its resources (Afuah, 2003, Mahoney and Pandian, 1992). As the resources and competences differ between industry sectors (Penrose, 1959), the emerging competence gaps (Pennings and Puranam, 2001) may be closed by cross-industry collaborations (Bower, 2001). Therefore, companies are sourcing in these missing competences during convergence processes.

Following an exploratory approach, the longitudinal case study in Chapter 4 analyses the functional food sector while scrutinising the cross-industry collaborations of two leading food (Nestlé/Danone) and two leading pharmaceutical (Martek/Bayer HealthCare) companies. For the purpose of deriving a measurement approach for convergence from a collaboration perspective, publicly available data about mergers and acquisitions, licensing agreements, strategic alliances and joint ventures is used to identify the different kinds of cross-industry collaborations. In order to analyse these collaboration forms, the following two determinants are used: motivation of collaboration (exploitation – exploration) and industrial scope of collaboration (within one industry sector – inside-out, outside-in, coupled process). Against this backdrop, Chapter 4 addresses the following research question:

*RQ3 What kinds of cross-industry collaborations can be used to close competence gaps?*

The evaluation of the cross-industry collaborations of the four companies stemming from the food and pharmaceutical sectors delivers a research framework that can be used to analyse the emerging inter-industry segment. The motivation of collaboration as well as the industrial scope of collaboration can be used as determinants for the likelihood of companies using the different forms of cross-industry collaborations.

Beyond the analysis of market and industry convergence from the cross-industry collaboration level, consumer awareness of the inherent product characteristics is pivotal for a successful product launch (Verbeke, 2005, Weststrate et al., 2002). Regarding the emerging area between foods and drugs, the inherent product characteristics encompass functional ingredients, such as probiotics or phytosterols. Given the importance of ingredient awareness for successful product launches, the aim of the fourth empirical part of this thesis (Chapter 5) is to explore consumers' ingredient awareness and its determinants answering the following research question:

*RQ4 How can convergence be assessed using a consumer perspective?*

A sample of 200 German consumers was interviewed via computer aided telephone interview (CATI). The participants were asked about their specific awareness of ten functional food ingredients. Likewise, determinants such as health status and health motivation were assessed, and their influence on the construct '*consumers' ingredient awarene*ss' was tested by employing structural equation modelling. Structural equation modelling delivers an approach to depict this intertwined relationship between the determinants of ingredient awareness, which can be used to derive a communication strategy of borderline products, thus of functional foods. Furthermore, the level of consumers' ingredient awareness may reflect the relevance of the convergence area.

In Chapter 6, the thesis discusses the contributions of the four chapters, providing an overview of the answers to the research questions regarding the assessment of convergence from different perspectives. In addition, the integration of the different perspectives is considered with a focus on the overall research questions (ref. Figure 1-1). The results of this research are specifically relevant for actors from the food and pharmaceutical sectors active in the rapidly changing environment of the emerging borderline products of functional foods. Moreover, this study contributes to the academic research on convergence while delivering different perspectives to analyse the complete convergence process, which have not been applied in former literature on convergence. The exploratory approaches on the step of market and industry convergence in particular enhance the literature about the convergence phenomenon. In summary, the following figure (ref. Figure 1-4) provides an overview of the different parts of the thesis related to the above-described theoretical background.

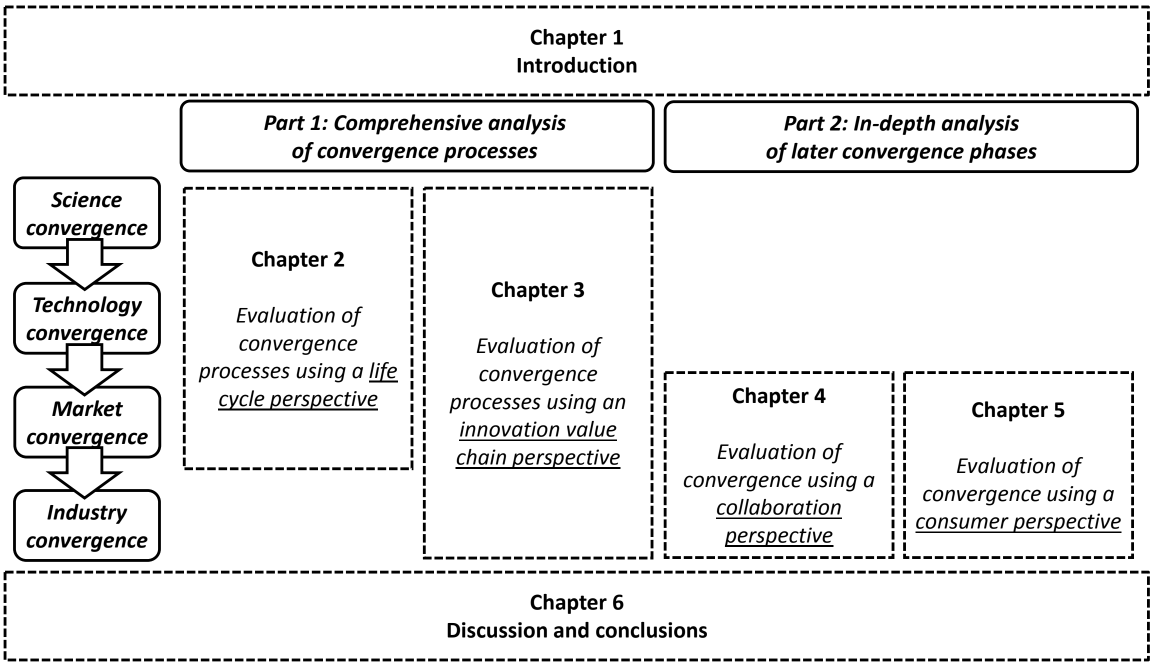


*Figure 1-4: Thesis setup*

# 2 Evaluation of convergence processes using a life cycle perspective

**Chapter 2 answers Research Question 1.1 and 1.2:**

*1.1 To what extent can cross-industry activities be depicted in life cycles?*

*1.2 What kinds of life cycle patterns can be identified in the convergence process?*

*This chapter is based on the following publication: "BORNKESSEL, S., BRÖRING, S. & OMTA, S. W. F. 2015. Crossing industrial boundaries at the pharma-nutrition interface in probiotics: a life cycle perspective. PharmaNutrition, 4, 29-37"*

## 2.1 Introduction

For almost 40 years, the idea of converging industries has fascinated researchers and practitioners alike. First studies can be observed in the late 1970s with the initial identification of convergence in the area of the computing and telecommunication systems (Farber and Baran, 1977). Subsequently, with the growing interest in this research field numerous studies exist which focus on the overlapping segments triggering the emergence of a new industry field of information and communication technology (ICT) (e.g. Bröring and Leker, 2007, Henderson and Clark, 1990, Katz, 1996, Prahalad, 1998). Another but less well understood example of convergence is the functional food sector which emerges at the interface of the food and the pharmaceutical industries (Bröring et al., 2006, Omta, 2004). This industry segment comprises products delivering nutritional as well as health value. The converging segments of food and pharmaceutics are characterised by cross-industry activities (Bornkessel et al., 2014) resulting in rapid market changes.

These rapid market changes in converging industries can be analysed by means of life cycle concepts (e.g. Herrmann, 2010, Höft, 1992) as in general life cycles are defined as '*a progression through a series of differing stages of development*' (Farlex, 2014). Considering the distinct concepts of life cycles, these focus on various objects such as products, technologies, organisations or industries (Höft, 1992). Although there are some attempts to relate specific concepts such as the patent life cycle (Ernst, 1997) to converging industries (Curran, 2010, Weenen et al., 2013c), the literature on applying life cycle concepts to measure convergence processes is rather scarce in general and, yet, has not seen a wide application on the setting of functional food convergence. Furthermore, the literature regarding the evaluation of converging industries addresses mainly the front end of the process including science and technology convergence as they focus on the anticipation of convergence processes (see for instance Curran et al., 2010). Hence, literature regarding the assessment of market and industry convergence is rather limited, particularly in the emerging area at the borderline of foods and drugs.

Related to this particular case, a growing number of different functional ingredients has become available on the food market especially within the last decade (Ares et al., 2008a). Accordingly, the food ingredient category of probiotics presents a rather young group besides the more classical functional ingredients such as vitamins and minerals. Food products containing probiotics are of a high relevance for the rapidly changing food market and the related innovations (MarketsandMarkets, 2010). From a market perspective, dairy products enriched with probiotics are one of the most successful functional foods on the market, especially looking at the rise of the new category of daily-dose drinks in small bottles (Saxelin et al., 2005). Probiotics are defined as *'live microorganisms, as they are consumed in adequate numbers confer[ring] a health benefit on the host'* (Stanton et al., 2001). Probiotics belong to a group of functional ingredients that may improve gut health and boost the immune system (Verhagen et al., 2010).

In this context, the overall aim of this chapter is to analyse cross-industry activities in convergence at the interface of the food and pharmaceutical sectors using the example of probiotics. In doing so, the first three steps of science, technology and market convergence are analysed from a life cycle perspective – especially including the evaluation of market convergence as the consecutive step following science and technology convergence. Based on bibliometric data sets including scientific publications, patents and news reports, life cycle indicators are applied to the process of convergence. As the existent literature on the application of the life cycle concept to convergence processes encompassing cross-industry activities is scarce, the study follows an exploratory approach leading to a research framework to assess science, technology as well as market convergence.

The remainder of this chapter is structured as follows. In the next section (2.2), the theoretical background of life cycle patterns in converging industries will be described. Concurrently, different measures for the application of life cycle concepts will be compared. Section 2.3 will detail the methods of gathering bibliometric data. Section 2.4 will present the results regarding the bibliometric analysis of science, technology and market convergence as well as cross-industries activities in the research setting of probiotics. Finally, this chapter will discuss the findings and their implications for academics and practitioners alike, before concluding with an outlook on future research possibilities.

## 2.2 Theoretical background: The life cycle concept in convergence processes

### 2.2.1 Cross-industry activities in convergence processes

Convergence has been presented in the extant literature by using various definitions. These definitions share the common idea, which is summarised by the Organisation for Economic Co-operation and Development (OECD) as follows: *'the blurring of technical and regulatory boundaries between sectors of the economy'* (OECD, 1992). This implies that formerly distinct industrial areas start to produce similar products in an emerging field of new approaches such as for example the telecom industry and camera technology sector developing the new segment of camera phones (Hacklin, 2008) or the segment of functional foods at the intersection of the pharmaceutical and food sectors leading to borderline products such as probiotic yoghurts (Bröring, 2005).

Moreover, dimensions of convergence are discussed as a process rather than a steady state following the steps of science, technology, market and industry convergence (ref. detailed description in 1.2 and for instance Bröring, 2005, Curran et al., 2010, Curran, 2010, Hacklin, 2008). With an increasing level of diversification during convergence processes, companies perform best when they are more integrated in different knowledge resources (Nasiriyar et al., 2014), which could be resembled by cross-industry activities of companies from distinct industrial backgrounds.

As convergence processes are based on the activity of different industry sectors, cross-industry activities occur during this merging process (Bornkessel et al., 2014, Preschitschek, 2014, Sick et al., 2015). Cross-industry innovation is based on knowledge, technologies, and partners with a high cognitive distance, which remains a current research field on innovation management (Enkel and Gassmann, 2010), as the resulting radical innovations are of a high relevance for companies (Bader, 2013). The need for the different competences of the different industry sectors might lead to competence gaps of the involved firms (Pennings and Puranam, 2001). Furthermore, the stretch of resources to serve the adjacent industry, resp. emerging inter-industry segment might result in competence gaps (Pennings and Puranam, 2001), since innovation barriers are industry-specific (Weenen et al., 2013b). Companies' strategic actions to close the arisen competence gaps encompass the internalisation of external assets for instance through the acquisition of companies or strategic alliances (Bower, 2001, Gambardella and Torrisi, 1998). Thus, the competence base of hitherto distinct industry sectors starts to become alike.

The research setting of this study of probiotics belongs to the functional food sector, as a new inter-industry segment between the food and pharmaceutical sectors. The research and development investments of the European food industry is much lower than in other sectors (Costa and Jongen, 2006) as for example in the pharmaceutical sector. The pharmaceutical sector is characterised as a research-intensive sector (Howells et al., 2008). This leads to strong competences in research and development for the pharmaceutical sector, whereas the food sector is more consumer market-oriented (Bröring, 2005). In other words, the core competences of one sector will appear as competence gaps of the other sector, while the research and market areas of these two sectors converge. Although external collaborations along the value chain seems to be underdeveloped in the food sector (Lindgaard Christensen et al., 2011), collaborations in the emerging area of functional foods will become increasingly important due to the growing market interest.

The subsequent theoretical perspective to analyse cross-industry activities in convergence processes is based on the life cycle concept, which originated in biology and is adapted in marketing research

(Faßbender-Wynands and Beuermann, 2001, Herrmann, 2010). The steps are commonly defined as introduction, growth, maturity and decline (Herrmann, 2010, Höft, 1992). One possibility to categorise the different approaches is the framework delivered by Höft (for a detailed description see Höft, 1992). This categorisation is based on the different objects of life cycles: products, technologies, organisations and industries. Thereby, the technology life cycle respectively the industry life cycle are both concepts, which aggregate the underlying life cycles of products respectively organisations on a higher abstraction level (Höft, 1992, Porter and Brandt, 2013). Furthermore, specialised concepts focusing on one certain area of life cycle concepts are described in literature. For instance, the patent life cycle introduced by Ernst based on the *s*-curve concepts of technologies is one approach to measure the life cycles of technologies (Ernst, 1997). As a further example, the product generation life cycle extends the product life cycle perspective incorporating the sum of the product life cycles of the associated products, which are connected to one product generation (Fortuin, 2007, Garbade et al., 2013).

In literature, technology life cycles are often combined with an analysis of patent data leading to a patent life cycle (Ernst, 1997, Haupt et al., 2007). The patent life cycle can be divided into the three phases of emergence showing a slight increase in the amount of patent applications, followed by a consolidation phase leading to a high increase in patent applications during the market penetration of a technology (Ernst, 1997). In derogation from the traditional life cycle concept, the patent life cycle considers a consolidation phase between the emergence (introduction) and market penetration (growth). This consolidation phase describes the reorientation of research efforts based on first market experiences of the new technology (Ernst, 1997).

Patent analyses are used for the depiction of technology life cycles (Haupt et al., 2007) and for the description of on-going processes in the context of converging industries, especially to scrutinise technology convergence (see for instance Jeong et al., 2015, Karvonen and Kässi, 2011, Kim and Kim, 2012). Therefore, the usage of patent data as a measurement tool for technology life cycles, which in turn are used to describe converging industries, presents a current research field (Gao et al., 2013). Especially for industry sectors arisen at the interface of foods and pharmaceutics such as the medical nutrition sector, the consideration of patent data is of importance due to the protection of intellectual property (Weenen et al., 2013a). In addition, (industry) life cycle concepts hardly consider the dynamics of relationships between actors from different industries (Peltoniemi, 2011). However, these cross-industry relationships are of great importance in the context of on-going convergence processes as they could be used to close the arisen competence gaps.

The life cycle concept might be one approach to reflect the rapid market changes in the emerging sector at the food and pharmaceutical interface and therefore an on-going convergence process, which leads to cross-industry activities. Against this backdrop, the first research question is:

*RQ1.1 To what extent can cross-industry activities be depicted in life cycles?*

### 2.2.2 Life cycle patterns in convergence processes

The idealised time series of convergence events encompass the four steps of science, technology, market and industry convergence (see for instance Curran et al., 2010). The technology life cycle indicators introduced by Watts & Porter may be used to operationalise the measurement of convergence processes in general based on the technology life cycle approach (Järvenpää et al., 2011, Watts and Porter, 1997). Relating the idealised time series of convergence events to these life cycle indicators, firstly, the step of science convergence corresponds to the fundamental research measured by scientific publications. Secondly, the level of technology in convergence processes resembles the life cycle indicator of applied research and development measured by patent data. Thirdly, the market convergence, where new product-market combinations emerge, is equivalent to the application in life cycle indicators, which can be reflected by news reports on product launches.

Relating the two described concepts of life cycle indicators and the patent life cycle, the idealised curve shape of the patent life cycle might be extended to the application of the other life cycle indicators. That means scientific publications are used to measure science convergence and news reports on product launches to measure market convergence while identifying the occurrence of new product-market combinations drawn from different industrial backgrounds.

In summary, the convergence process might be assessed employing life cycles applied to each convergence level (scientific publications for science convergence, patents for technology convergence and reported product launches for market convergence). The curve shapes might appear in form of the patent life cycle. Thereby, a time lag is postulated between the occurrence of scientific publications and patents according to the described consecutive steps of convergence processes (see for instance Curran, 2010). Furthermore, following the time series of events another time lag between technology and market convergence might be postulated (ref. Figure 2-1).

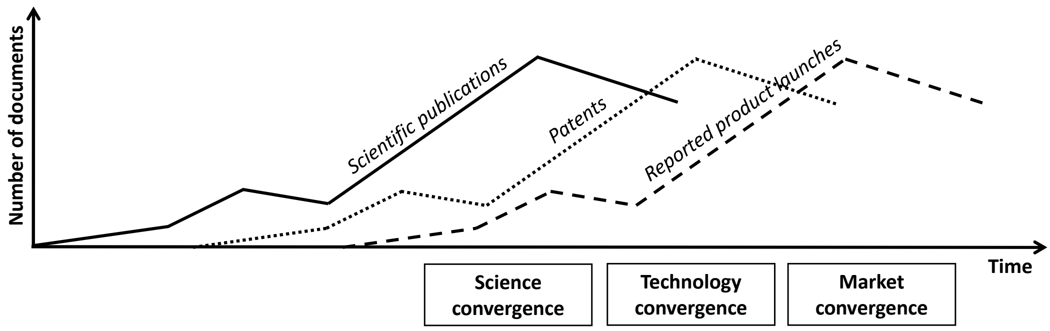


*Figure 2-1: Life cycles measuring the convergence process*

Furthermore, relating this concept to the convergence process, this study strives to consider the different industry sectors involved and their cross-industry activities. Therefore, these idealised curves can be shown for each publication type separated for the distinct industry sectors and for the cross-industry activities resembled by the joint activity of different industrial backgrounds. The curve shapes of the diverse industrial backgrounds might have maxima at different moments in time. These different curves might not occur simultaneously. Cross-industry activities might result from the earlier activities of distinct industrial backgrounds. Therefore, the occurrence of the cross-industry activities may take place at a later stage. In addition, the speed in development might differ between the different industry sectors due to the distance to the emerging field and therefore the difficulties of closing the arisen competence gaps. Moreover, the clockspeed of an industry is commonly defined as the speed of the product life cycle, which differs between industry sectors (Carrillo, 2005, Fine, 1998) and is driven by the new product development (Carrillo, 2005). While the general concept states a difference between the clockspeed of industry sectors due to the length of the product life cycles (Fine, 1998, Mendelson and Pillai, 1998), the clockspeed of convergence can be measured by length of the time lags between science, technology and market life cycles as the inception of the next phase in convergence is reached when the next life cycle starts. The question arises how the involved industry sectors differ in their clockspeed within the science, technology and market convergence. Based on the discussion about difference in curve shapes, thus life cycle patterns, this leads to the second research question:

*RQ1.2 What kinds of life cycle patterns can be identified in the convergence process?*

### 2.2.3 Research framework

Against this theoretical background, the study in this chapter aims to analyse life cycle patterns in the research setting of the food and pharmaceutical industries. Accordingly, the evaluation of the first three steps in the idealised time series of convergence events is based on the assessment framework of life cycle indicators identifying differences in life cycle patterns of scientific publications, patents and reported product launches. Furthermore, this study distinguishes between the convergence process of the involved industry sectors while showing the science, technology and market life cycles for each involved sector and for their cross-industry activities. In addition, the reported product launches are scrutinised considering the market outlet of the launched products (ref. Figure 2-2).

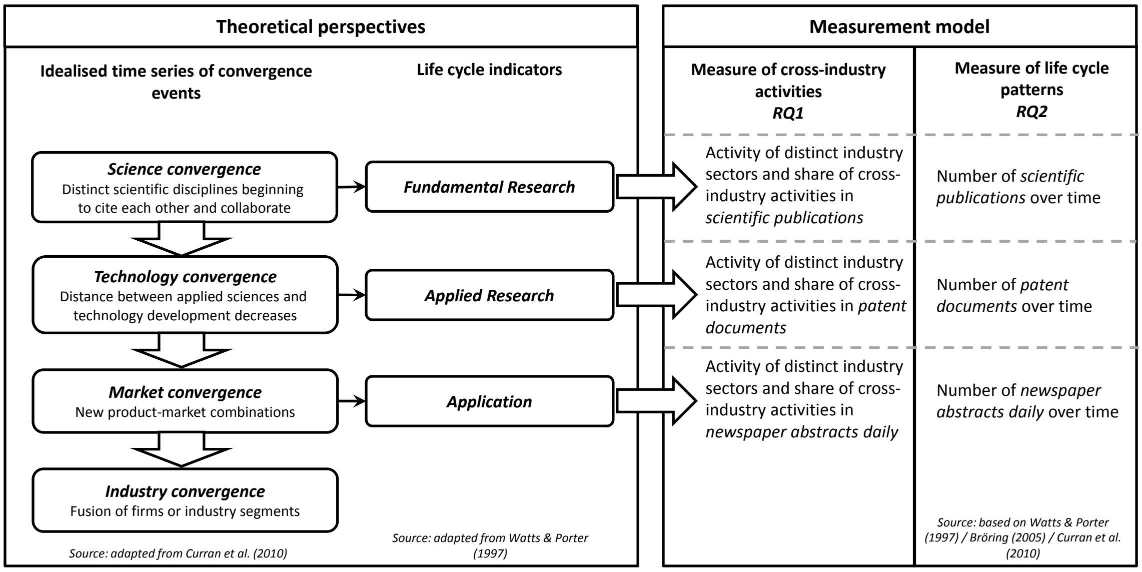


*Figure 2-2: Research framework*

## 2.3 Methods and measurement

### 2.3.1 Scientific publications and patent documents

In the present study, 8,245 scientific publications and 2,082 patent documents published worldwide considering the functional ingredient category of probiotics were analysed. The search term used was *'probiotic*'*. For both document types duplicate entries and non-company entries were excluded. Furthermore, this study concentrates on convergence, thus the industrial perspective. The top 50 organisations were included leading to 629 considered scientific publications and 527 considered patents. This study evaluated a 20-year period between 1990 and 2009. Hence, the essential steps of the convergence process in probiotics were covered (see for instance Bornkessel et al., 2014). As the study at hand entails the application of the life cycle concept to the convergence process encompassing the steps of science, technology and market convergence, the necessary period was enclosed. The Thomson Innovation software tool was used. This software tool is a platform that facilitates analysis of intellectual property, scientific literature and business data (Thomson Reuters, 2011). It draws upon the DWPI (Derwent World Patents Index), a database, which categorises patent documents using a classification system for all technologies. Standard Industrial Classification (SIC) codes (U.S. Securities and Exchange Commission, 2011) were used to analyse the industrial background of the patent filing companies. This study focused on the four industry segments on the subject of the analysis of scientific publications and patents: food, pharmaceutics, chemistry and personal care. Furthermore, collaborative activities of different industry sectors in one scientific publication / patent / reported product launch were defined as cross-industry activities.

### 2.3.2 News reports including new product announcements

To identify launches of products containing probiotics, this study follows a quantitative approach using the database Nexis to screen the news reports using a time frame reaching from 1990 to 2009 (ref. to scientific publications and patent documents using the same time frame). The used search term was '*probiotic*'* to screen news reports with the following setting: All News, all languages. This data source encompasses all full-text and selected abstract news sources regardless of the language (Nexis, 2015). Furthermore, the news reports were limited to the predefined category of '*new products'*. Therefore, this study focused on the new product announcements in the area of probiotics. As all news reports were included, different target groups were addressed by the different news resources, for instance newspapers aimed at consumers and business journals aimed at scientific and industrial experts in this field. To identify the real product launches, each news report was screened to exclude the non-relevant announcements such as for instance market reports. In addition, double announcements of one product launch were eliminated leading to 359 reported product launches. Furthermore, the industrial background of the launching company was determined based on SIC codes. Based on each reported product launch, the product category used as market outlet was determined. The categorisation is as follows: food, dietary supplements (OTC[3]) and other.

The timely development of scientific publications, patent documents and reported product launches in general as well as for each involved industry sector is depicted. Based on the idealised curve shape of the patent life cycle, a function with two maximal and one minimal turning point is expected. Hence, a polynomial function of 4$^{th}$ degree was used to calculate the trend line for each life cycle in Excel 2013. In addition, the local and global maxima and minima were calculated based on curve sketching to determine the life cycle phases.

## 2.4 Results

### 2.4.1 Life cycle patterns in science, technology and market

Generally, an increase in the number of scientific publications, patent documents and news reports focusing on product launches in the research field of probiotics can be observed (ref. Figure 2-3). By means of the above presented idealised time series of convergence processes, firstly, distinct scientific disciplines show research and development output in the field of probiotics indicated by the activity in publishing scientific articles. Secondly, the distance between applied sciences and technology development decreases shown by the increase of activity in patenting. Thirdly, the news reports on the launches of probiotic products illustrate market convergence with an increasing amount of reported product launches. High $R^2$ show an appropriate goodness of fit.

[3] OTC = over the counter. This includes all non-prescribed products, which are sold in pharmacies, drugstores and supermarkets.

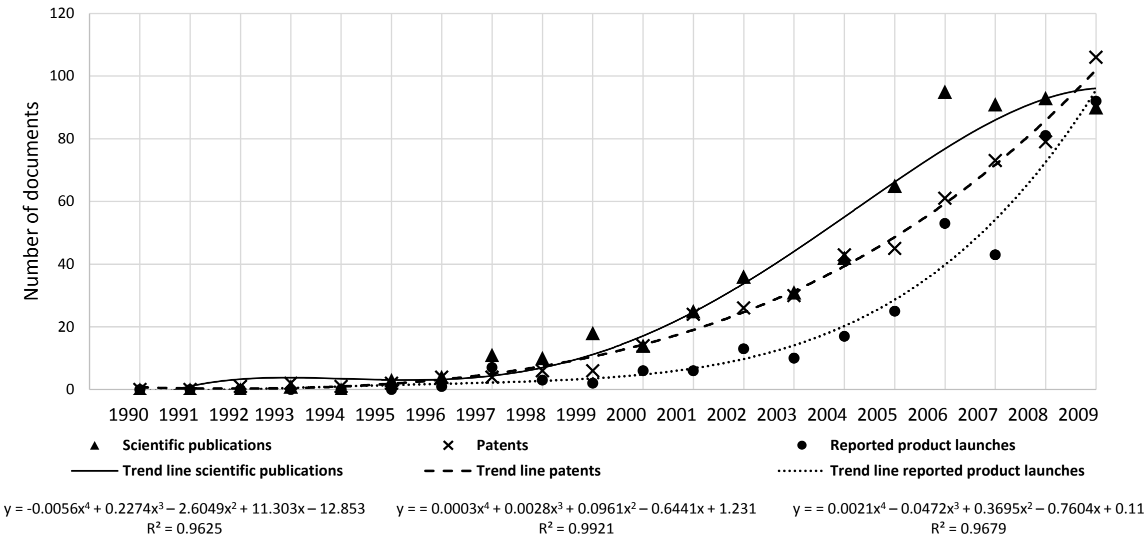


*Figure 2-3: Comparison of the life cycles of scientific publications, patent documents and reported product launches*

In case of scientific publications, a global maximum is identified immediately after 2009 indicating the introduction and growth phase leading up to 2010 where maturity will be reached. As the trend line for scientific publications shows a local minimum between 1995 and 1996, at this point the emergence of the science life cycle in probiotics can be shown indicated by the consecutive increase. Examining the trend line for patent documents, a global minimum between 1991 and 1992 can be shown indicating a still on-going increasing trend for patent documents in which maturity cannot be yet defined. In the context of the life cycle concept, the growth phase continues. Like in patent documents, the trend line of reported product launches shows a global minimum (1990/1991) indicating an on-going growth phase.

By applying the life cycle concept to the three levels of convergence (science, technology and market), different patterns emerge. First, the findings confirm the time lag initially identified by Curran et al. (2010) between science and technology convergence. Moreover, this study extends the notion of the consecutive steps to the level of market convergence also showing a time lag between technology and market convergence.

### 2.4.2 Science, technology and market life cycles of the distinct industrial backgrounds showing cross-industry activities

Relating the life cycle concept to converging industries, the comparative consideration of the sectors involved for each step (science, technology and market convergence resembled by scientific publications, patents and news reports focusing on product launches) is important to identify time lags as well as differences in the clockspeed of the involved industry sectors. In the area of probiotics, the active industrial backgrounds are the food, the pharmaceutical, the personal care and the chemical sector. The number of documents published by the food sector outnumbers those from the other sectors. Due to the dominance of this sector, for the subsequent analysis the categories are used as follows: food sector, summary of pharmaceutical, chemical and personal care sector as well as cross-industry activities (ref. Figure 2-4). The high number of scientific publications by cross-industry collaborations shows the interest of distinct industry sectors in the area of probiotics and therefore might constitute an indication of on-going convergence processes. Again, high $R^2$ show an appropriate goodness of fit.

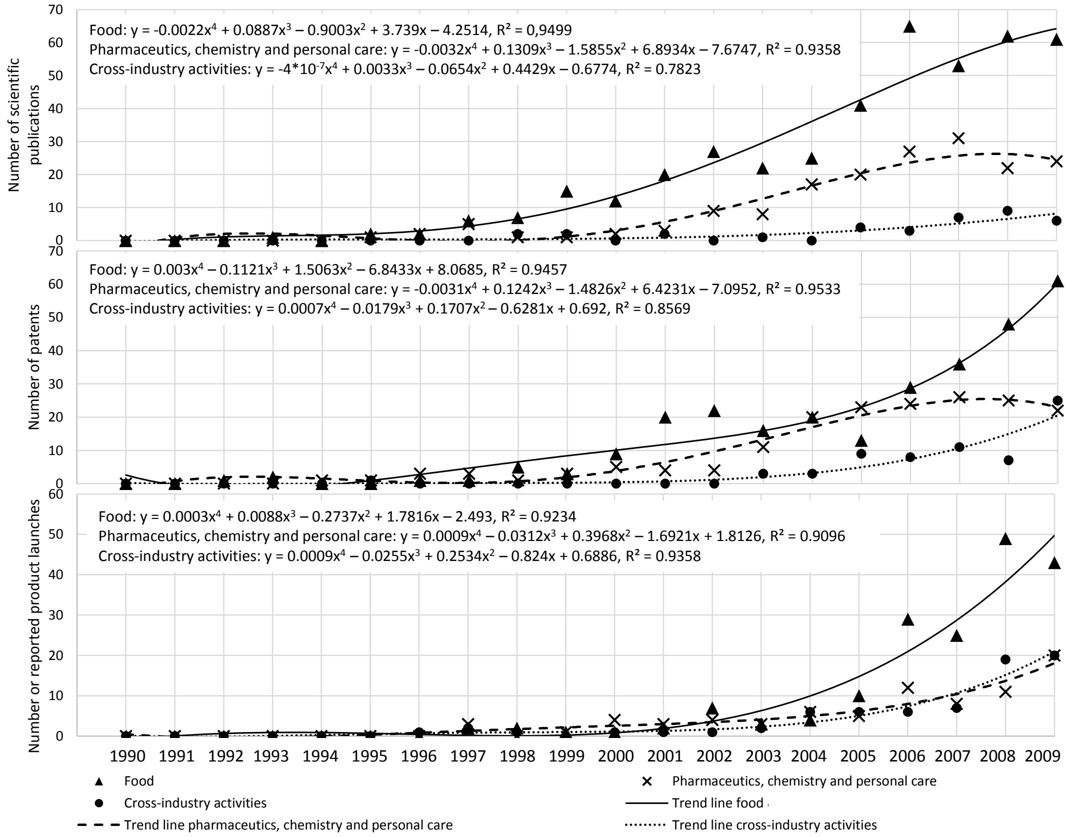


*Figure 2-4: Number of scientific publications, patent documents and reported product launches according to the industrial background of the publishing companies*

In summary, there is a shift over time regarding the life cycles showing the same activities of companies of distinct industry sectors at different times resulting in time lags. The distance between the starting points of the activity of the different industrial backgrounds is the largest in scientific publications and the smallest in reported product launches. Overall, the food sector seems to have a higher growth rate, thus a faster diffusion pace than the other sectors, which is typical for the food sector delivering *fast moving consumer goods* (FMCG). In addition, the clockspeed – thus the time lags between the life cycles – is higher in the food sector indicating a faster adoption time.

### Phase determination of scientific publications

The food trend line of scientific publications will reach its global maximum in approximate 2010, thus the maturity phase will be reached. In case of pharmaceutics, chemistry and personal care, the trend line shows two local maxima and one local minimum. Firstly, the local minimum is directly at the beginning of the considered period. The first maximum is reached between 1992 and 1993 and the second in 2008. According to the patent life cycle, there might be a short consolidation phase after 1992, before reaching the second growth phase, which reaches its maximum in 2008. After 2008, there seems to be a decline phase. The trend line of cross-industry activities shows a calculated global maximum in about 4,000 years, thus the science life cycle of cross-industry activities remains in the early phases and the polynomial function cannot depict the further realistic development.

### Phase determination of patent documents

Examining the patent trend line of the food sector, a global minimum between 1992 and 1993 can be shown indicating a still on-going increasing trend for patent documents in which maturity cannot be yet defined. Like in scientific publications, the trend line of the pharmaceutical, chemical and personal care sector shows two local maxima and one local minimum. Whereas the local minimum is immediately at the beginning of the considered period, the first local maximum is between 1992 and 1993 and the second between 2007 and 2008, thus one year earlier than in scientific publications. Related to the patent life cycle, there might be a short consolidation phase after 1993, which is terminated by the consecutive increase indicating the growth phase. In case of cross-industry activities, there can be identified one global minimum between 1992 and 1993 indicating a still on-going increasing trend for patent documents.

**Phase determination of reported product launches**

Regarding the considered period, the trend line of the reported product launches of the food sector shows one local minimum and one local maximum. The local maximum is already reached between 1993 and 1994, whereas the local minimum follows 5 years later between 1998 and 1999. The local minimum might indicate the consolidation phase referring to the patent life cycle concept having between the emergence and the growth phase of the life cycle a decline. In case of pharmaceutics, chemistry and personal care, there can be identified one global minimum directly at the beginning of the considered period indicating a still on-going increasing trend of product launch announcements in which maturity cannot be yet defined. The same holds true for the trend line of cross-industry activities.

### 2.4.3 Market outlet

The reported product launches are analysed regarding their market outlet, therefore the product categories are as follows: *functional foods, dietary supplements (OTC)* and *other*. Firstly, *functional foods* summarises all applications in food products such as fortification in yoghurt drinks. Secondly, the category *dietary supplements (OTC)* encompasses all products in a drug-like appearance, which are sold ‘over the counter’ without a prescription in pharmacies, drugstores or supermarkets. These products are sold for instance as pills, powder or gels (Eussen et al., 2011). Thirdly, the category other summarises the remaining application areas such as feed, drugs, cosmetics or speciality products such as gardening products.

The industry sectors show different levels of activity in the aforementioned product categories (ref. Table 2-1). Overall, the food sector and the cross-industry activities concentrate on functional food products, whereas the pharmaceutical sector concentrates on dietary supplements. As depicted in Figure 2-4, the cross-industry activities occur mainly from 2008, whereas the food sector reports already a high number of product launches three years earlier in 2005. This time lag might be because competence gaps of single companies are closed by collaborations resulting in later product launches. Overall, functional food products dominate the product launches containing probiotics as main market outlet of the food sector. Functional food products are first in the probiotics market followed by product launches of dietary supplements, which increase over time. Thus, according to the general time lag between the food and pharmaceutical sector in product launches, this can be also shown for the market outlet with firstly functional food products and secondly OTC products launched. Therefore, the clear dominance of functional food products is apparent. Examples of supplements launched by the food sector are for instance probiotic drops, which are sold in pharmacies. Exemplary functional food products launched by the pharmaceutical sector are for instance chewing for children.

*Table 2-1: Activity of industry sectors in different product categories**

| Industry sector | Functional foods | Supplements (OTC) | Other | Total |
|---|---|---|---|---|
| **Food** | 161<br>48.6 % | 6<br>1.8 % | 11<br>3.3 % | 178<br>53.8 % |
| **Pharmaceutics, chemistry and personal care** | 12<br>3.6 % | 55<br>16.6 % | 13<br>3.9 % | 80<br>24.2 % |
| **Cross-industry** | 55<br>16.6 % | 13<br>3.9 % | 5<br>1.5 % | 73<br>22.1 % |
| **Total** | 228<br>68.9 % | 74<br>22.4 % | 29<br>8.8 % | 331<br>100 % |

** Numbers indicate the counted reported product launches for each category*

## 2.5 Discussion

Assessing convergence processes at the intersection of the food and pharmaceutical industries from a life cycle perspective, the consecutive phases can be measured by life cycle indicators drawing upon the analysis of scientific publications, patents and reported product launches. Yet, a shift over time can be seen considering the life cycles showing the same activities of companies of distinct industry sectors at different times resulting in time lags. The earlier activity of the food sector might be due to a closer distance of the new emerging area to this industry sector as most products are launched in the functional food category. Furthermore, the diffusion time of industry sectors might differ due to their distance to the new emerging field.

**Cross-industry activities depicted in life cycles at the intersection of food and pharmaceutics (RQ1.1)**

As the activity of different industrial backgrounds, e.g. the pharmaceutical and chemical sectors, increases over the considered period indicated by the increase of submitted scientific publications and filed patents resulting in reported product launches, signs of an on-going convergence process in probiotics are evident. Especially the huge increase of patents filed through cross-industry activities in the later years confirms this phenomenon. In addition, these cross-industry activities support the definition of this emerging area to be a complementary convergence process (Bröring and Cloutier, 2008). The industrial backgrounds focus on the new segment of for example probiotics enriched yoghurt drinks, while the traditional areas of food products (yoghurt) and pharmaceutical products (drug containing probiotics) remain. Furthermore, the higher number of alliances across industries might lead to a higher degree of research specialisation (Zidorn and Wagner, 2013) resulting in new borderline products.

Cross-industry innovation based on knowledge, technologies, and partners with different competences (Enkel and Gassmann, 2010) can be shown in converging industries as these processes are based on different industry sectors leading to cross-industry innovation characterised by borderline products. In the case of probiotics, there is a clear difference between industry sectors in the first increase of scientific publications and patents (ref. Figure 2-4). Nevertheless, the increase in reported product launches occurs almost at the same time. The increase of cross-industry activities might be due to differences in research and development resulting in a simultaneous product launch based on cross-industry alliances or joint ventures. The arisen competence gaps due to the distance of the involved sectors in basic research might be closed by cross-industry activities. Although the pharmaceutical industry relies on intellectual property rights (Howells et al., 2008), in case of probiotics the food sector outnumbers the patents of the pharmaceutical sector. The dominance of the food sector in the reported product launches might be due to the innovation approach of the introduction of a relatively high amount of different products in a short time span (Costa and Jongen, 2006). These cross-industry activities start after activity of the food sector. Furthermore, an increasing degree of convergence through science, technology and market convergence can be linked to the growing number of cross-industry activities.

Although the earlier development steps are characterised by activities from distinct industrial backgrounds, the main market outlet for probiotics is in the form of functional food products. This might be due to the dominating food sector. Based on that main functional food market outlet, one reason for the increasing cross-industry activities might be that for instance the pharmaceutical sector requires the marketing strengths of the food sector to launch a functional food product successfully. This product category as such shows a convergence of the food and pharmaceutical sectors as those products deliver a health benefit beyond the nutritional value. Therefore, the evaluation of these borderline products might be used as a measure for market convergence as market convergence describes the new product-market combinations.

**Life cycle patterns at the intersection of foods and pharmaceutics (RQ1.2)**

The application of the patent life cycle to the different levels of convergence delivers one approach to scrutinise the different phases of convergence in the case of the food and pharmaceutical sectors. Especially the evaluation of market convergence measured by the number of reported product launches provides one possibility to consider this area that has been neglected in the recent literature (see for instance Curran et al., 2010). However, the sole consideration of the overall amount of news reports might not be enough to analyse market convergence as the same topic can be repeated in several news reports for example published by different journals or newspapers. Therefore, the conducted analysis of the therein reported product launches could provide an approach to evaluate the emerging product-market combinations during market convergence. In addition, borderline products present market convergence as such, as they integrate different competences of the involved industry sectors. Therefore, the further analysis of the market outlet considering potentially arising new product categories could describe market convergence. The dominance of the food sector in probiotics is confirmed as functional food products are the main category of launched products.

Extending the patent life cycle to the three levels of convergence (ref. Figure 2-1), the different phases of the life cycles do not seem to be as static as in the theoretical approaches. The consolidation phase, which is hypothesised in the patent life cycle to occur between the emergence and growth phase, does not seem to be found in every case. In the respective literature, the consolidation phase for patents encompasses the reorientation of research and development efforts based on the first experiences with new technology in the market (Ernst, 1997). This reorientation process could also be shown for the science life cycle of the pharmaceutical, chemical and personal care sectors as after the first description of a scientific issue, e.g. the detection of a certain probiotic strain, further research might take a new focus. As the consolidation phase cannot be shown universally, the curve could be adapted in the form of showing firstly a slight increase (introduction phase) directly followed by an increase with a steep incline (growth phase). This non-static performance of the life cycle might be due to two reasons discussed in the literature: firstly, lack of or weak opportunities for process innovations, which leads to significant scale advantages and secondly, major product innovations may disrupt existing (product) life cycles and shape new life cycles (Christensen, 2013). Detecting new life cycles might enable companies to observe new trends.

Focusing on the phases of convergence processes, in the literature these are described to be consecutive. Therefore, there might be a time lag between each step (Curran et al., 2010). In case of probiotics, a time lag is confirmed between science and technology as well as between technology and market convergence. Beyond the interpretation of a time lag, the identification of the first phases and their occurrence might deliver assumptions about anticipating on-going convergence processes, which confirms recent literature about the anticipation of convergence processes by evaluating science and technology convergence (Curran, 2010, Curran et al., 2010, Daim et al., 2006). As the step of market convergence is already reached in probiotics, future studies could concentrate on the following step of industry convergence evaluating fusion of firms or industry segments.

As regards the clockspeed of industries, this concept seems useful to explore the convergence phases. The food sector dominates the field of probiotics by driving science, technology and market convergence showing earlier activity in scientific publications, patents and product launches by having a higher clockspeed of the life cycle phases. In the probiotics case emerging at the intersection of the food and pharmaceutical sectors, the categorisation of the pharmaceutical industry as a high-value research-intensive sector is supported, which launched products linked to the science base (Howells et al., 2008).

**Concluding remarks**

This chapter extends the evaluation of the consecutive convergence steps to market convergence. This allows to deliver a framework with which to determine the driving sector(s) in each convergence step by the dominance of the amount of documents in the different periods. Furthermore, the pace of reaching the different convergence phases of distinct industry sectors (clockspeed) is another indicator for the dominance of certain industry sectors. The cross-industry activities measured by the number of collaborative documents help to identify on-going convergence processes. More specifically, this allows to analyse the competitive environment, especially through depicting the cross-industry relationships between single companies. From an academic perspective, this study delivers a research framework with which to analyse converging processes including the specific market convergence steps. In addition, the consideration of cross-industry activities using a life cycle perspective provides a dynamic view over time to analyse current developments and to gain first insights in the anticipation of future developments. While the theoretical contribution evolves around the explanation of convergence characteristics in science, technology and market focusing on cross-industry activities, practical contributions lie in the transferability of the employed methodology to other areas of (potential) convergence and their easy applicability. Managerial implications arise from the great strategic importance of converging industries, enabling firms to identify processes at an early stage and prepare for changes in demand structures, technological shifts, and future competitors.

However, the sole consideration of bibliometric data is not adequate to describe and explain the dynamics in convergence processes. Therefore, events such as changes in regulations should also be considered as determinants of life cycles as distinct regulations show differences in their impact on the innovation performance (Rennings and Rammer, 2011). Especially, the on-going discussion about the possible health effect of probiotics led by the European Food Safety Authority might have an influence on the life cycle patterns in probiotics. Furthermore, as focus lies on product launch announcements, this study only considers those launches, which are published in news reports. The real number of product launches might be higher than the ones considered in this study. The determination of the phases should be adapted to each single case as the definition is dependent of the total amount of documents. Further studies could derive a general framework of assessing the different phases.

When discussing the value of bibliometric analysis including scientific publications, patents and news reports in terms of converging industries, one generally needs to take into account that these documents deliver a useful information source as they contain detailed information and are quite readily available, although the period of 18 months between application and publication must be considered. This information also includes the industrial background of the active company. That is one reason for the usefulness of bibliometric analysis in the case of converging industries. Bibliometric analysis delivers a nearly holistic view on co-operations between different companies but the complexity of collaborations cannot be shown in these data sets. Therefore, further research could concentrate on a more qualitative approach of analysing collaborations in terms of convergence processes. Although the study at hand covers the three steps of science, technology and market convergence, the convergence process in the area of probiotics is still on-going; therefore, the life cycles could be further extended. Furthermore, the adaptability of the derived methodological framework might be tested in other cases to validate it.

# 3 Evaluation of convergence processes using an innovation value chain perspective

**Chapter 3 answers Research Question 2:**

*How can convergence be assessed using an innovation value chain perspective?*

*This chapter is based on the following publication: "BORNKESSEL, S., BRÖRING, S. & OMTA, S. W. F. 2014. Analysing indicators of industry convergence in four probiotics innovation value chains. Journal on Chain and Network Science, 14, 213-229."*

## 3.1 Introduction

The relevance of cross-industry innovation has increased in recent decades with a growing number of inter-industry fields emerging on the borderline between formerly distinct industries (e.g. Bröring et al., 2006, Farber and Baran, 1977, Hacklin, 2008, Henderson and Clark, 1990, Omta, 2004). This phenomenon of convergence is defined in multifaceted terms in the extant literature but follows the common idea summarised by the Organisation for Economic Co-operation and Development as follows: *'the blurring of technical and regulatory boundaries between sectors of the economy'* (OECD, 1992). With the blurring of boundaries between hitherto distinct industry sectors, the importance of cross-industry relationships along innovation value chains increases (Enkel and Gassmann, 2010). Concurrently, further convergence indicators such as science or competence convergence can be used to set up a framework of indicators analysing convergence processes.

Convergence of computing and telecommunication was first mentioned in the late 1970s (Farber and Baran, 1977). With the growing interest in this research field, numerous publications can be found focusing on the overlapping industry fields of information and communication technology (Bröring and Leker, 2007, Henderson and Clark, 1990, Katz, 1996, Prahalad, 1998). A recent example of convergence can be found in the functional food sector that emerges on the borderline between the food and pharmaceutical industries (Bröring et al., 2006). Product examples of this emerging field are, for instance, cholesterol-lowering margarine with phytosterols and products benefiting the immune system such as probiotics (Verhagen et al., 2010). Probiotics in particular represent a growing market segment (Stanton et al., 2001). Probiotics are defined as *'live microorganisms, as they are consumed in adequate numbers confer[ring] a health benefit on the host'* (Stanton et al., 2001). Following this definition, the microorganisms – different strains of bacteria – are the value-generating ingredients of probiotic products.

Beyond that, the aim of this study is to analyse convergence in probiotics innovation value chains. Therefore, this study assesses convergence with distinct indicators, concurrently relating these indicators to the innovation value chain perspective. Thereby, this study follows an exploratory approach to derive propositions. Consequently, this study aims to answer the following research question:

*RQ2 How can convergence be assessed using an innovation value chain perspective?*

The remainder of this chapter is structured as follows. In Section 3.2, this study focuses in detail on convergence showing different indicators to analyse convergence derived from the literature. This study provides an in-depth description of the indicators of convergence as follows: cross-industry relationships along the innovation value chain, science, technology, regulatory and competence convergence. Section 3.3 encompasses the sample and methods of the study. In Section 3.4, the results are presented starting with the identification of the companies active in the area of probiotics, followed by the companies' indicators of convergence. Finally, the findings and their implications for academics and practitioners alike are discussed, before concluding with an outlook on future research possibilities.

## 3.2 Theoretical background: Indicators of convergence

### 3.2.1 Cross-industry relationships along innovation value chains

In many studies, the convergence concept is primarily associated with technology convergence. However, it is a multifaceted phenomenon, which should not be reduced to the technology level (Borés et al., 2003, Nyström, 2008). Moreover, dimensions of convergence are discussed as a process rather than a steady state leading to the consecutive steps of science, technology, market and industry convergence (ref. detailed description in 1.2 and for instance Bröring, 2005, Curran, 2010, Curran et al., 2010, Hacklin, 2008).

The research and development phase within value chains is commonly defined as the discovery of new knowledge, which is then used to create new and improved products (Kaplinsky and Morris, 2000). Furthermore, the first two phases of the innovation value chain introduced by Hansen and Birkinshaw focus on idea generation and conversion (Hansen and Birkinshaw, 2007). This corresponds firstly to science convergence with the discovery of knowledge from neighbouring publishing disciplines and secondly, technology convergence with the application of a technology (Figure 3-1). The commercialisation phase within value chain analysis respectively the idea diffusion phase within innovation value chains is the step of the delivery to final consumers (Hansen and Birkinshaw, 2007, Kaplinsky and Morris, 2000), which overlaps with the market and industry convergence step where new product-market combinations arise (Bröring, 2005, Preschitschek, 2014). Therefore, the consideration of the innovation value chain in the context of convergence is of great importance as the partners within the innovation value chain are still the most important sources of knowledge used to develop inventions (Enkel and Gassmann, 2010, Giuri et al., 2007). In the context of convergence, these partners stem from different industrial backgrounds reflected by cross-industry relationships. Beyond that, the first proposition focusing on the first indicator of convergence can be derived:

*P1: If probiotics innovation value chains converge, companies will show cross-industry relationships along the innovation value chain.*

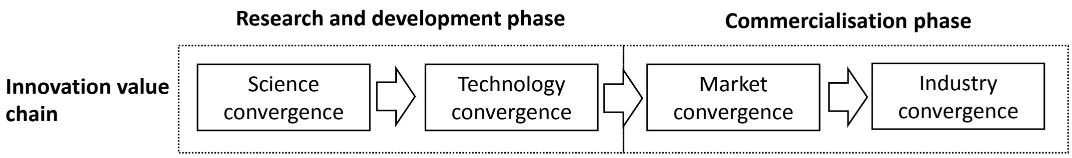


*Figure 3-1: Convergence along the innovation value chain*

Based on the literature focusing on convergence processes, further indicators beside the cross-industry relationships along the innovation value chain can be identified, for instance regulatory or competence convergence (e.g. Bröring, 2005, Curran, 2010, Gambardella and Torrisi, 1998, Katz, 1996, Yoffie, 1997). In the following sections, the indicators of convergence based on the aforementioned consecutive steps are discussed first, followed by the indicators independent from the procedural view.

### 3.2.2 Science convergence

In the literature, science convergence underlines the importance of knowledge as a basis for convergence processes (Guilhon, 2001, Pennings and Puranam, 2001). Following the idealised time series of convergence, the first step encompasses science convergence implying that distinct scientific disciplines begin to cite each other (Curran, 2010, Curran et al., 2010). Furthermore, collaborations of scientific disciplines (e.g. collaborations of different departments of one university or different universities) are part of the initial step of convergence. Based on this diversification, competence gaps might be closed. Moreover, scientific communities start to publish not only in their own research area but also in other areas. Therefore, the subject areas of the scientific publications (e.g. topics) differ from their own research area. Beyond that, science convergence can be measured by an elaboration of scientific publications and their subject areas (Curran et al., 2010). These analyses encompass the elaboration of the industrial background of the publishing parties and the publications' scientific subject areas. This leads to the second proposition:

*P2: If probiotics innovation value chains converge, companies will show science convergence.*

### 3.2.3 Technology convergence

Likewise the multifaceted definitions of convergence in general, technology convergence is variously described and defined within the literature (see for instance, Kim and Kim, 2012, Nyström, 2008). In some studies, technology convergence is put on the same level as convergence (Borés et al., 2003). This might be due to the fact that the general idea of convergence goes back to the overlapping of technologies (Rosenberg, 1976, Stieglitz, 2002). However, there are also attempts to clearly delineate technology convergence from the general convergence concept (Katz, 1996). Following a definition by Hacklin (2008), technology convergence *'denotes the transition of knowledge convergence into a potential for technological innovation, allowing inter-industry knowledge spill-overs to facilitate new technological combinations'* (Hacklin, 2008). Thereby, technology convergence is the translation of science convergence into technological innovation (Hacklin, 2008, Curran, 2010) or in other words knowledge is the underlying basis for technology convergence (Kim and Kim, 2012)[4]. In line with the idea of the convergence of technologies being a driver of convergence, the underlying technological platforms of the formerly distant industry sectors become more alike (Fai and von Tunzelmann, 2001, Gambardella and Torrisi, 1998). Following this reasoning one can assume that application areas (as detailed in patents) of the commonly used technology platforms are becoming increasingly broad as they build the basis of product development for two different industries. Furthermore, this serves as an indicator of companies' approaches to closing the resulting competence gaps.

Several studies have already used patents to scrutinise and anticipate industrial developments like convergence on the technological level (Bröring, 2005, Curran, 2010, Curran et al., 2010, Daim et al., 2006, Ernst, 1998, Liu and Shyu, 1997). Patent analyses encompass the elaboration of the industrial background of the patenting companies and the patents' application areas. Thereby, subject areas describe the topic of the patent. Consequently, the third proposition can be deduced:

*P3: If probiotics innovation value chains converge, companies will show technology convergence.*

### 3.2.4 Market convergence

When considering market convergence, the central idea is that formerly distinct industrial areas start to produce similar products in an emerging field of new approaches (Gambardella and Torrisi, 1998). Given that these products combine different functions and underlying technologies, convergence on the market level can be observed (Bröring, 2005, Preschitschek, 2014). This definition focus mainly on the demand side of the market, whereas first measurement approaches of market convergence primarily focus on the supply side using collaborations of companies from different industrial backgrounds (Preschitschek, 2014, Sick et al., 2015). Focusing on the demand side, the hybrid products in case of probiotics are in the form of foods and dietary supplements such as dairy products and baked products. Such probiotic products are claimed to modulate gut microbial composition, thereby leading to improved gut health (Stanton et al., 2001). They are hybrid products as they show the appearance of traditional food products originating from the food industry and concurrently deliver a health benefit beyond the nutritional value incorporating functions from drugs – rooted in the pharmaceutical industry.

As the aim of this study is to explore convergence in four probiotics innovation value chains, this study uses the presence of market convergence (demand side) as the chosen criterion for the research objects assuming a further developed convergence process. Accordingly, this study identifies the

[4] As knowledge is discussed as a basis for science and for technology convergence, it becomes clear that a delineation of both constructs is characterised by blurring boundaries; for a further discussion see for instance Curran (2010).

companies based on the available probiotic products on the market considering the specific probiotic strains.

### 3.2.5 Regulatory convergence

In addition to the consecutive steps of science, technology and market convergence leading to industry convergence, regulatory convergence appears to be highly important especially in the case of probiotics because of the on-going process of changing regulations with regard to functional foods. Regulatory aspects are highly industry related, as distinct legislation is applicable to different products. Regulatory convergence can be defined as *'the growing similarity of institutional frameworks, policy approaches and outcomes in the field of regulatory politics'* (Falkner and Gupta, 2009). Based on this definition, regulatory convergence encompasses inter alia the emergence of new legislative texts or standards. This might be due to the changing industrial environment or, indeed, the regulation could be triggering convergence (Bröring, 2005). However, regulation is mostly discussed as a barrier to convergence (Katz, 1996). In the area of functional foods, the most prominent example of an emerging legislative text in Europe is the health claim regulation (EC No. 1924/2006). The emergence of this regulation encompassing the communication of health-related issues for nutritional products, e.g. the application of clinical trials to food products, shows tendencies of an on-going regulatory convergence process. Furthermore, the application of the regulation by different industry sectors can be used as an indicator to identify convergence in regulation. Therefore, companies' activities in obtaining health claims (and related to this, the conducting of clinical trials to file dossiers to be evaluated by the European Food Safety Authority) serves as an indicator for convergence in regulation. Therefore, the fourth proposition can be derived:

*P4: If probiotics innovation value chains converge, companies will show convergence in regulatory compliance.*

### 3.2.6 Competence convergence

Concurrently with the upcoming versatility and the need for different competences, the stretching of resources to serve the adjacent industry, resp. emerging inter-industry segment, might lead to competence gaps in the firms involved (Pennings and Puranam, 2001). Therefore, the literature on convergence processes also focuses on the role of individual business actions (Curran, 2010) to deal with the convergence related challenges (Katz, 1996, Yoffie, 1997). Therefore, the second indicator beside the consecutive steps of convergence can be summarised by the term *'competence convergence'*. This concept encompasses companies' strategic actions in terms of competence activities to close competence gaps or in other words the internalisation of assets (Gambardella and Torrisi, 1998). One way of meeting the challenge of upcoming competence gaps is the internalisation of external assets through the acquisition of companies (Bower, 2001, Gambardella and Torrisi, 1998). Furthermore, competence gaps can be closed through licensing agreements and strategic alliances. Therefore, competence convergence is reflected by the analyses of mergers and acquisitions, licensing agreements and strategic alliances assuming that companies are sourcing-in the missing competence.[5] Thus, the competence base of hitherto distinct industry sectors starts to look similar. This leads to the fifth proposition:

*P5: If probiotics innovation value chains converge, companies will show competence convergence.*

Furthermore, a distinction can be made between technology-driven input-side convergence and market-driven output-side convergence (Bröring, 2005) refining the general concept of demand-side and supply-side convergence processes (Malhorta and Gupta, 2001). In this scenario, the technology-

[5] As described above, recent studies discuss cross-industry collaborations as a measure for market convergence (Preschitschek, 2014, Sick et al., 2015).

driven input-side convergence evolves from new technologies which are applied across distinct industry sectors, whereas market-driven output-side convergence evolves from the customers changing the functions of a product by adding or dropping some options for use (Bröring, 2005). Both concepts can be of a substitutive or a complementary nature (Bröring, 2005). By that means, a substitutive process leads to industry fusion; two distinct industry sectors become one (*'1+1=1'*). A substitutive relation implies that the replacement of the conventional approaches proceeds. A complementary process is highlighted by the creation of a new value chain between the old ones leading to a new inter-industry segment (*'1+1=3'*). The case of functional foods is already defined in literature as a complementary process (e.g. Bröring and Cloutier, 2008). The study's example of probiotics belongs to the functional food sector, therefore might show a complementary process. The engagement of companies in the new emerging field is based on their individual strategic decisions, as the new sector is complementary to the existing ones. If companies aim at the new sector, their activities along the value chain can be divided into three categories: (a) *technology developers*; (b) *technology-intense product developers*; and (c) *product developers using existing technologies* (Bröring and Cloutier, 2008). Firstly, technology developers are characterised by new science-driven technology developments without a direct application to the consumer market. Secondly, new technology developments associated with direct use to form a consumer product are defined as technology-intense product developers. Thirdly, product developers using existing technologies show new consumer product developments with the intent of using existing external technologies (Bröring and Cloutier, 2008).

### 3.2.7 Research framework

Against this theoretical background, the study in this chapter uses a mixed-method approach (Johnson and Onwuegbuzie, 2004, Latcheva, 2011) to analyse convergence in four probiotics innovation value chains using quantitative and qualitative data. This study firstly identified the companies in the area of probiotics active in the different steps of the innovation value chain based on the products they sell in the market (market convergence). In the following, the unit of analysis were these identified companies. Concurrently, their cross-industry relationships were depicted showing the first indicator of convergence. Secondly, this study showed the further convergence indicators of the identified companies: science, technology, regulatory and competence convergence. Competence convergence showed a relationship with the other three indicators as the resulting competence gaps might be closed through convergence related behaviour on all levels. This study follows the structure shown in Figure 3-2 depicting an overview of the measures and data sources used for the convergence indicators. The four indicators for innovation value chains as well as science, technology and regulatory convergence were measured focusing on probiotics, whereas the indicator of competence convergence covers all strategic business activities of each company.

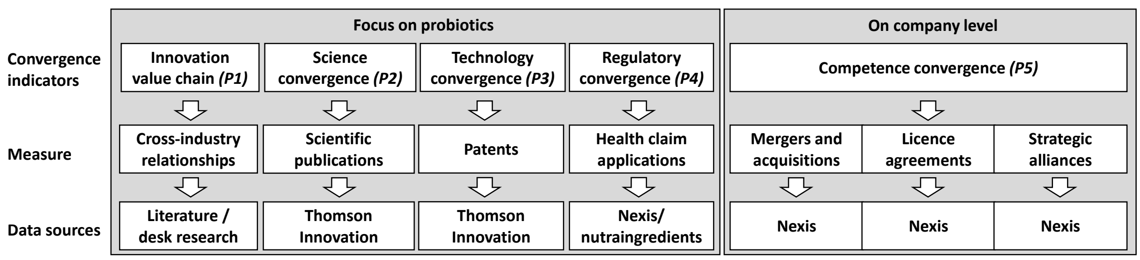


*Figure 3-2: Overview of study structure including the related measures and data sources*

The occurrence of cross-industry relationships is used to explore proposition *P1* as first indicator of convergence. Bibliometric analyses of scientific publications and patents deliver quantitative measures exploring the propositions *P2* and *P3*. Qualitative data is generated by analyses of the news reports with regard to health claims exploring proposition *P4*. The qualitative and quantitative analyses of competence convergence present a measure to explore proposition *P5*. The analysis of these convergence indicators is further described in the following subsections summarising the analyses of scientific publications and patents.

## 3.3 Methods and measurement

### 3.3.1 Identification of companies and their cross-industry relationships along innovation value chains

Following a qualitative approach, the creation of a list of probiotic strains currently available on the global market was established based on the report *'Global Probiotics Market'* by MarketsandMarkets in 2010 (MarketsandMarkets, 2010), scientific literature about probiotics (e.g. Siezen and Wilson, 2010) and further desk research. The focus lies on bacteria strains, which can currently be found in commercial dairy products. Hence, the commercial availability of the strains on the market serves as a selection criterion and depicts the dimension of market convergence (demand side). Four strains were chosen based on the market share of end products. The four bacteria strains are *Lactobacillus caseii* DN 114001, *Bifidobacterium lactis* Bb12, *Lactobacillus acidophilus* LA5 and *Lactobacillus rhamnosus*. These strains were used to identify the active companies. Furthermore, based on the above data sources, the general position of each company in the innovation value chain (research and development, B2B and B2C commercialisation) as well as their cross-industry relationships was determined[6]. The industrial background of the manufacturers was categorised according to Standard Industrial Classification (SIC) codes, a United States government system that indicates the company's type of business (U.S. Securities and Exchange Commission, 2011).

### 3.3.2 Bibliometric analyses – science and technology convergence

In line with earlier research, stressing the importance of scientific literature and patent analysis for analysing the first steps of convergence, this study scrutinised the companies of the probiotics innovation value chains with regard to their scientific publications and patents in the area of probiotics. This study analysed a part of the dataset gathered to study convergence in probiotics from a life cycle perspective (ref. Chapter 2). This study evaluated a period between 1990 and 2009 using the Thomson Innovation software tool. Thomson Innovation is a platform that facilitates analysis of intellectual property, scientific literature and business data (Thomson Reuters, 2011). It draws upon the Derwent World Patents Index, a database, which categorises patent documents using a classification system for all technologies. To classify scientific publications and patents, they were scrutinised on their application areas using the keywords in the title and abstract of each publication. By that means, the considered application areas are food, pharmaceutics and personal care, whereas the remaining scientific publications, which do not fit into one of these groups, were summarised in the category other, for instance general machinery or technical equipment.

### 3.3.3 Analysis of health claim applications – regulatory convergence

Based on the literature for analysing regulatory convergence, this study analysed the health claim submission activity of the companies in the probiotics innovation value chain. As there is no publicly available data on the applicants of health claims, a desk search from three angles was conducted: firstly, this study scrutinised the legislative texts summarised by Nexis, secondly, this study focused on the news reports also using Nexis and thirdly, a search on the website nutraingredients was conducted. For all three analyses, a period from 2006 to 2013 was used as the European health claim submission became law in 2006 and the on-going process of evaluating health claim submissions has not yet finished.

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[6] This categorisation is based on Boschloo (2011).

**Nexis legislative texts**

Using a qualitative approach, this study elaborated a period between 2006 and 2013 using the search mask *'legislative texts'* of Nexis focusing on European law. Nexis is a global provider of content-enabled workflow solutions (Nexis, 2015) using different global databases. The database on legislative texts encompasses full-text, English language EC/EU Treaties, Legislation, Preparatory Documents, National Provisions Implementing Directives, Parliamentary Questions, EFTA, and other documents as provided by EUR-Lex – the computerised documentation system on Community law, which the EU institutions makes available to their officials and the public.

**Nexis news reports**

Following a qualitative approach, this study elaborated a period between 2006 and 2013 using the search mask *'news reports'* using the following setting: major European publications.

**News search on nutraingredients**

A desk research on the website nutraingredients was conducted with the advanced search tool using the term *'health claim'* and the name of the company with the setting that all terms must be included in the search results. This study included all types of information sources. The news information on the website is based on a scan of all available scientific, technical and industry sources as well as a search of previously unpublished material, primary data and expert opinions (nutraingredients, 2013).

### 3.3.4 Competence convergence

Based on the literature for analysing competence convergence, a search of companies' strategies to close competence gaps was conducted from three angles: firstly, mergers and acquisitions, secondly, licensing agreements and thirdly, strategic alliances. Firstly, using a quantitative approach, this study evaluated a period between 1990 and 2013 using the search mask *'mergers and acquisitions'* of Nexis employing an analysis for every company of the probiotics value chain using the Mergerstat M&A database. This database provides detailed information on mergers, acquisitions and divestitures that are publicly announced for over 30 years. Secondly, following a qualitative approach, this study analysed the news reports considering the licensing agreements and strategic alliances in case of probiotics.

## 3.4 Results

### 3.4.1 Identification and categorisation of companies active in the global probiotics sector

The qualitative approach to identifying active companies in the area of the four probiotic strains delivers a total of 12 companies and one research organisation. The companies stem from the following four industrial backgrounds: food (5), pharmaceutics (5), chemistry (1) and personal care (1). The research organisation focuses its studies on the health care sector. Therefore, within the following results parts in Figure 3-3 to Figure 3-6 showing the innovation value chains of the four bacteria strains, the research organisation is categorised as stemming from the pharmaceutical sector.

Companies' characteristics such as sales, employees and the history of a company influence all their activities along the innovation value chain as well as strategic action in the context of convergence. Table 3-1 gives an overview of the identified companies based on publicly available data to be considered when interpreting further results. Furthermore, the company's activity in the four bacteria strains is listed.

*Table 3-1: Company characterisation based on sales, employees and history (data based on Nexis) and the company's activity in the four bacteria strains (data based on Boschloo, 2011)*

| Industrial background of company | Coding* | Sales (2012) | Employees | History | Activity in bacteria strains | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | *Lactobacillus Caseii DN 114001* | *Bifido-bacterium Bb12* | *Lacto-bacillus acidophilus LA5* | *Lacto-bacillus Rhamnosus* |
| | 1-1 | $99,498,193,520 | 328,00 | 1866 – up to date | | x | | |
| | 1-2 | $28,000,000,000 | 102,401 | 1966 – up to date | x | | | |
| ***Food*** | 1-3 | $17,700,000,000 | 41,000 | 1928 – up to date | | x | x | |
| | 1-4 | $2,691,918,649 | 4,447 | 1905 – up to date | | | | x |
| | 1-5 | $648,726,000 | 1,330 | 1992 – up to date | | x | | |
| | 2-1 | $3,330,963,048 | 4,818 | 1907 – up to date | | | | x |
| | 2-2 | No data available | 2,416 | 1957 – up to date | | x | | |
| ***Pharmaceutics*** | 2-3 | No data available | No data available | Patent in 1983 No further data available | | | x | |
| | 2-4 | No data available | No data available | Patent in 1989 + 1991 No further data available | | | x | x |
| | 2-5 | No data available | No data available | No data available | | | x | |
| ***Chemistry*** | 3-1 | $124,089,120 | 2,450 | 1874 – up to date | | x | x | |
| ***Personal care*** | 4-1 | $30,238,612,859 | 68,886 | 1909 – up to date | | x | | |
| ***Research organisation*** | 5-1 | No data available | No data available | 1887 – up to date | x | x | | |

** The first digit of the coding indicates the industrial background of the company and the second digit is used as a continuous numbering whereas the order is based on the sales in 2012 (if applicable).*

According to the company characteristics showing a dominance of the food sector, this study will focus in the following results sections firstly on the food sector and secondly, summarised in one group the pharmaceutical, chemical and personal care sector.

### 3.4.2 Innovation value chains

The following figures (Figure 3-3 to Figure 3-6) show the different innovation value chains for the four bacteria strains. In general, the value chains for the different bacteria strains are different according to the number of companies, the industrial backgrounds involved and the cross-industry relationships. In the following, this study will describe each innovation value chain in detail from a company-based view.

***Lactobacillus caseii* DN 114001**

The innovation value chain of *Lactobacillus caseii* DN 114001 is rather simple with the joint development of a research organisation focusing on the health care sector (5-1) and a company from the food sector (1-2). The joint research might be due to missing competences within the food company in the health care sector and, therefore, a closing of the competence gaps has arisen through convergence. After the joint development, the company processes and commercialises the bacteria strain. The food company is responsible for the research and development as well as the commercialisation phase, whereas the research organisation is only involved in the development of the probiotic product.

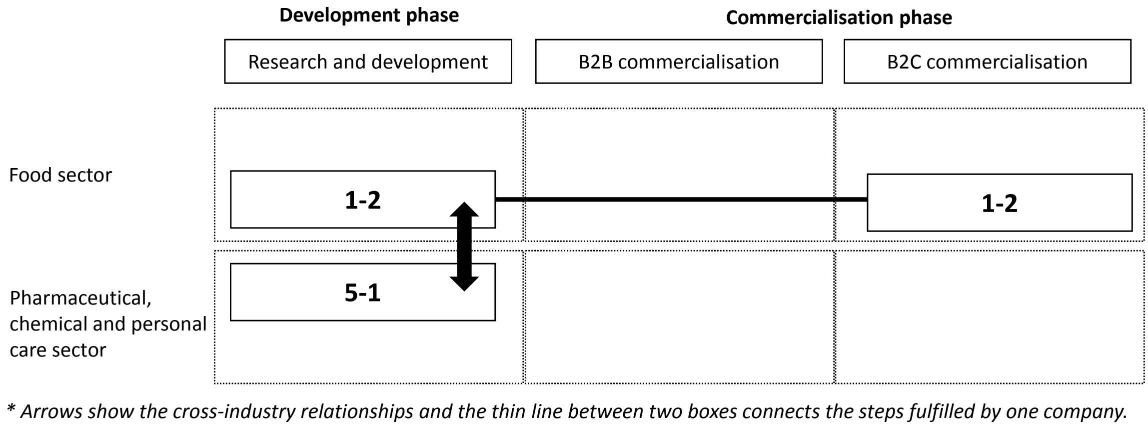



*Figure 3-3: Innovation value chain of Lactobacillus caseii DN 114001. Arrows show the cross-industry relationships and the line between two boxes connects the steps fulfilled by one company.*

### *Bifidobacterium lactis* Bb12

The innovation value chain depicting the relationships for the second bacteria strain *Bifidobacterium lactis* Bb12 shows cross-industry relationships vertically and horizontally between the chemical company (3-1) undertaking the two steps of development and B2B commercialisation and two companies from food (1-1; 1-5) and one from pharmaceutics (2-2). Thereby, the horizontal cross-industry relationship between the chemical (3-1) and food company (1-1) shows joint research (development layer), whereas the two other vertical relationships show buyer-supplier relationships. The research organisation (5-1) and the personal care company (4-1) show activities on the development layer without a relation to other companies or a further vertical integration in the value chain. One food company (1-3) takes up the position of B2C commercialising without activity on the development layer.

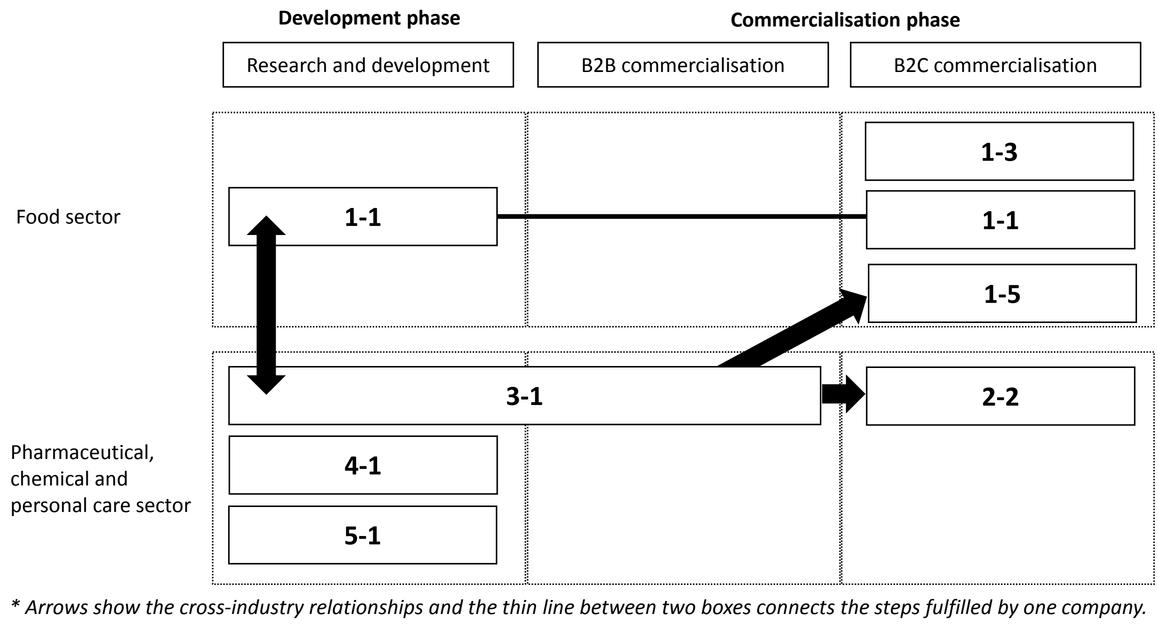



*Figure 3-4: Innovation value chain of Bifidobacterium lactic Bb12. Arrows show the cross-industry relationships and the line between two boxes connects the steps fulfilled by one company.*

### *Lactobacillus acidophilus* LA5

The innovation value chain of *Lactobacillus acidophilus* LA5 shows one vertical cross-industry relationship between the chemical company (3-1) and a pharmaceutical company (2-5). Along the innovation value chain, the chemical company fills the positions for development and B2B commercialisation, whereas the pharmaceutical company is responsible for the later B2C commercialisation. This association shows a buyer-supplier relationship. On the development layer, two pharmaceutical companies (2-3; 2-4) can be found showing no further integration along the innovation value chain. One food company (1-3) fills the position on the B2C commercialisation layer – also with no further integration along the innovation value chain.

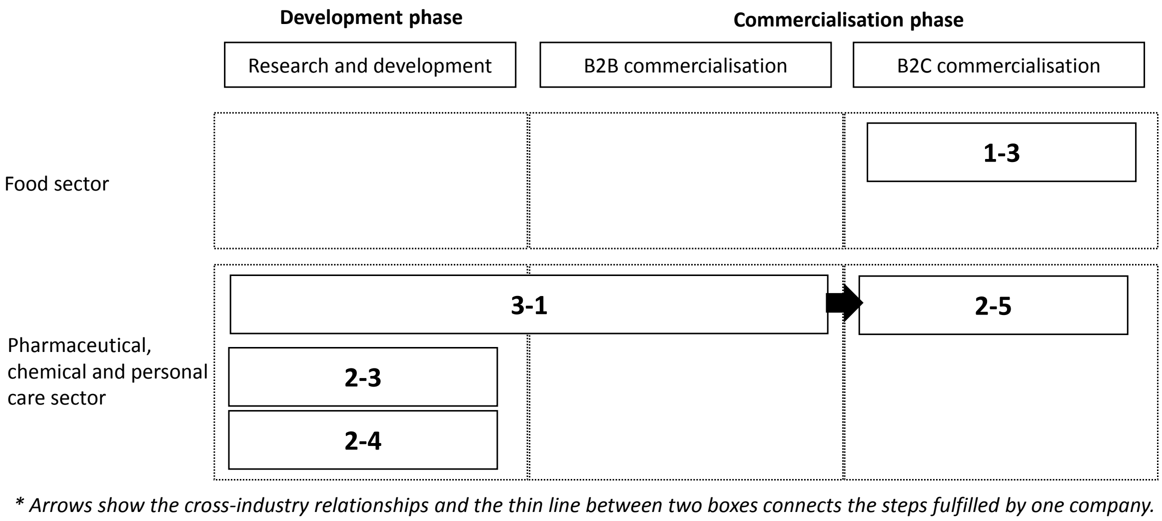



*Figure 3-5: Innovation value chain of Lactobacillus acidophilus LA5. Arrows show the cross-industry relationships and the line between two boxes connects the steps fulfilled by one company.*

### *Lactobacillus rhamnosus*

Three companies – one from the food sector (1-4) filling the positions for development and B2C commercialisation and two from pharmaceutics (2-1; 2-4) – build up the innovation value chain regarding the bacteria strain *Lactobacillus rhamnosus*. Although the food company is active on the development layer, there is a vertical buyer supplier relationship with the pharmaceutical company (2-4) active on the development layer. Furthermore, there is horizontal co-operation between the food company (1-4) and the second active pharmaceutical company (2-1).

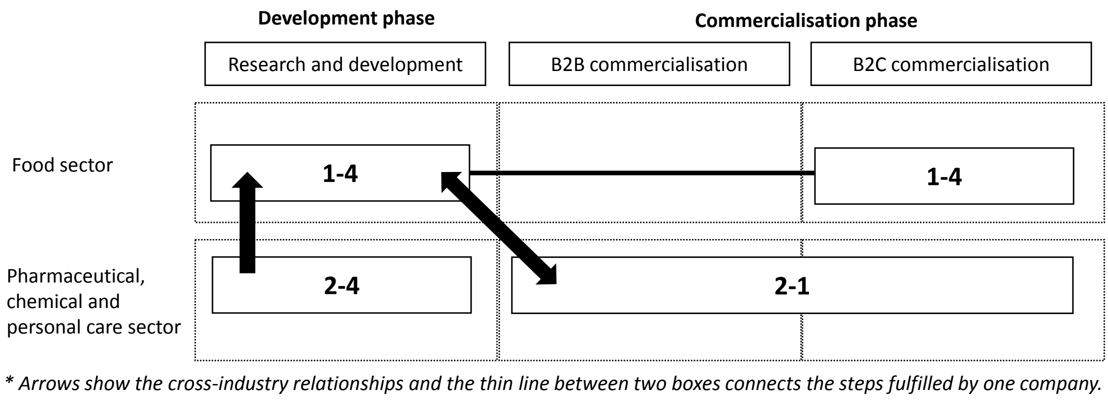



*Figure 3-6: Innovation value chain of Lactobacillus rhamnosus. Arrows show the cross-industry relationships and the line between two boxes connects the steps fulfilled by one company.*

In general, the food sector shows activity for all four bacteria strains. All industrial backgrounds are active for the *Bifidobacterium lactis Bb12* strain. The companies from the pharmaceutical sector show the second highest activity in terms of the involvement in the steps of development and commercialisation on B2C of the four bacteria strains. Summarising the results from the innovation value chains of these four bacteria strains, cross-industry relationships occur in all four cases at different stages of the innovation value chain supporting proposition *P1*.

Based on the summarised positions along the innovation value chains of the four bacteria strains, companies' different strategic types (Bröring and Cloutier, 2008) can be identified (Table 3-2).

*Table 3-2: Categorisation of strategic types based on company's position along the probiotics innovation value chain*

| Industrial background | Coding | Position in the value chain | | | Identified strategic types | |
|---|---|---|---|---|---|---|
| | | Research and development | B2B commercialisation | B2C commercialisation | | |
| ***Food*** | 1-1 | x | - | x | b) | Technology-intense product developer |
| | 1-2 | x | - | x | b) | Technology-intense product developer |
| | 1-3 | - | - | x | c) | Product developer using existing technologies |
| | 1-4 | x | - | x | b) | Technology-intense product developer |
| | 1-5 | - | - | x | c) | Product developer using existing technologies |
| ***Pharmaceutics*** | 2-1 | - | x | x | c) | Product developer using existing technologies |
| | 2-2 | - | - | x | c) | Product developer using existing technologies |
| | 2-3 | x | - | - | a) | Technology developer |
| | 2-4 | x | - | - | a) | Technology developer |
| | 2-5 | - | - | x | c) | Product developer using existing technologies |
| ***Chemistry*** | 3-1 | x | x | - | a) | Technology developer |
| ***Personal care*** | 4-1 | x | - | - | a) | Technology developer |
| ***Research organisation*** | 5-1 | x | - | - | a) | Technology developer |

Within the food sector, the two strategic types of *'technology-intense product developer'* and *'product developer using existing technologies'* can be found. The companies in the pharmaceutical sector show the *'product developer using existing technologies'* strategic type and the *'technology developer'* strategic type. The research organisation and the chemical and personal care company show characteristics of *'technology developers'*.

### 3.4.3 Science convergence

In general, it can be stated that in the context of convergence several of the identified companies are publishing in fields other than their own – in other words, in other subject areas supporting *P2*. Thereby, the intensity differs between the distinct industry sectors as explained in the following. Regarding scientific publications, this study analyses whether these publications are related to convergence. Thereby, convergence related scientific publications are those publications focusing on other industry sectors than the one the publishing company comes from.

In general, the activity in science convergence focusing on probiotics of the companies in the food sector is highest. Most of these scientific publications are related to convergence as they focus on the pharmaceutical sector. Two companies from the food sector (1-3; 1-5), the research organisation and the companies from the pharmaceutical sector are not active in scientific publications. Furthermore, there are also scientific publications published by companies from the food and chemical sector, which focus on more than one subject area. These publications as such show science convergence, as research from the publishing company must be done in an area of industry different from their own. The results regarding the scientific publications of the identified companies support *P2* and are shown in Figure 3-7. Thereby, the number is the absolute number of scientific publications in a specific subject and the percentage value shows the percentage of scientific publications in the respective subject area. The same applies to Figure 3-8 to Figure 3-11.

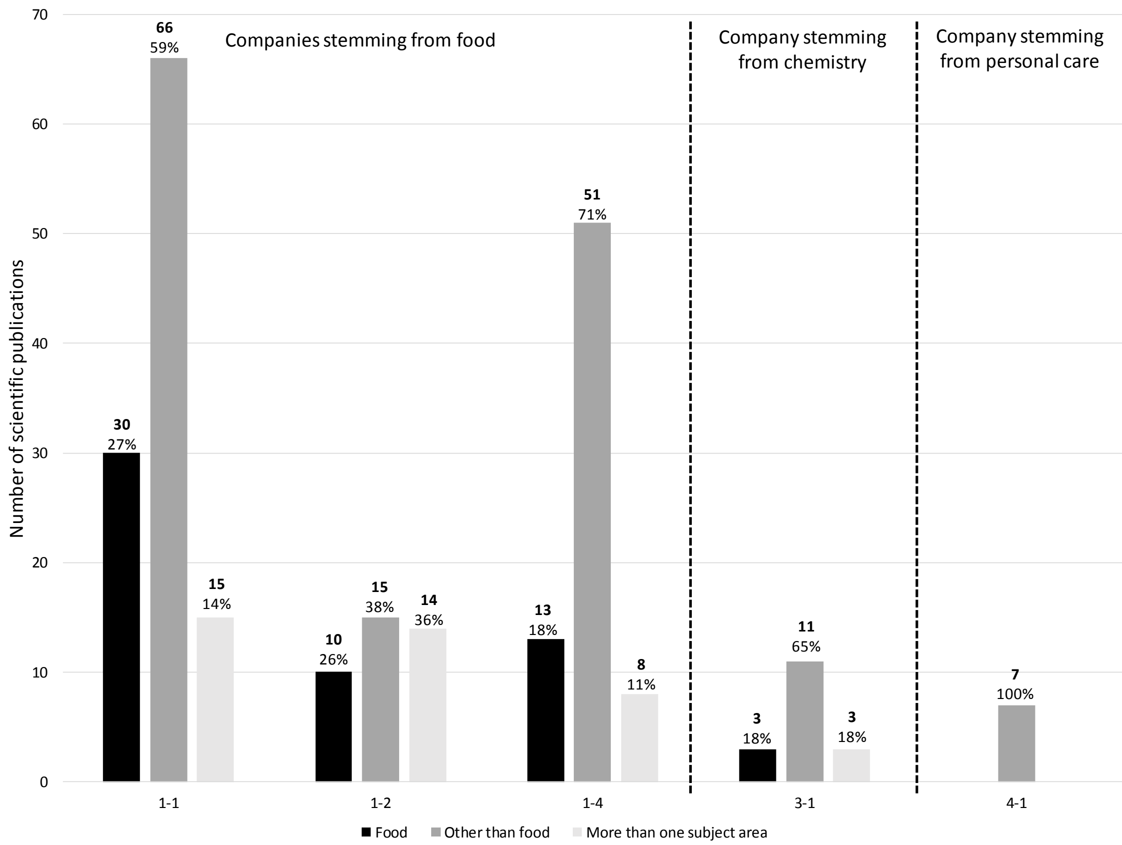



*Figure 3-7: Scientific publications as a function of the publishing company and the publication's subject area*

### 3.4.4 Technology convergence

Regarding technology convergence, this study analyses whether the patents are related to convergence. Thereby, convergence related patents are those focusing on other industry sectors than the one in which the patenting company is active. As shown in Figure 3-8, in general the patenting activity focusing on probiotics of the companies in the food sector is highest. Most of the patents that are convergence related focus on the pharmaceutical sector. The companies from the pharmaceutical sector are not active in patents with regard to probiotics. Furthermore, there are patents focusing on more than one subject area, thus showing convergence. These results support proposition *P3*.

Moreover, there are differences in the publishing and patenting behaviour. Based on the higher number of convergence related scientific publications than patents, publishing in a research area other than the own traditional field seems to be more likely than patenting in other areas in the case of probiotics.

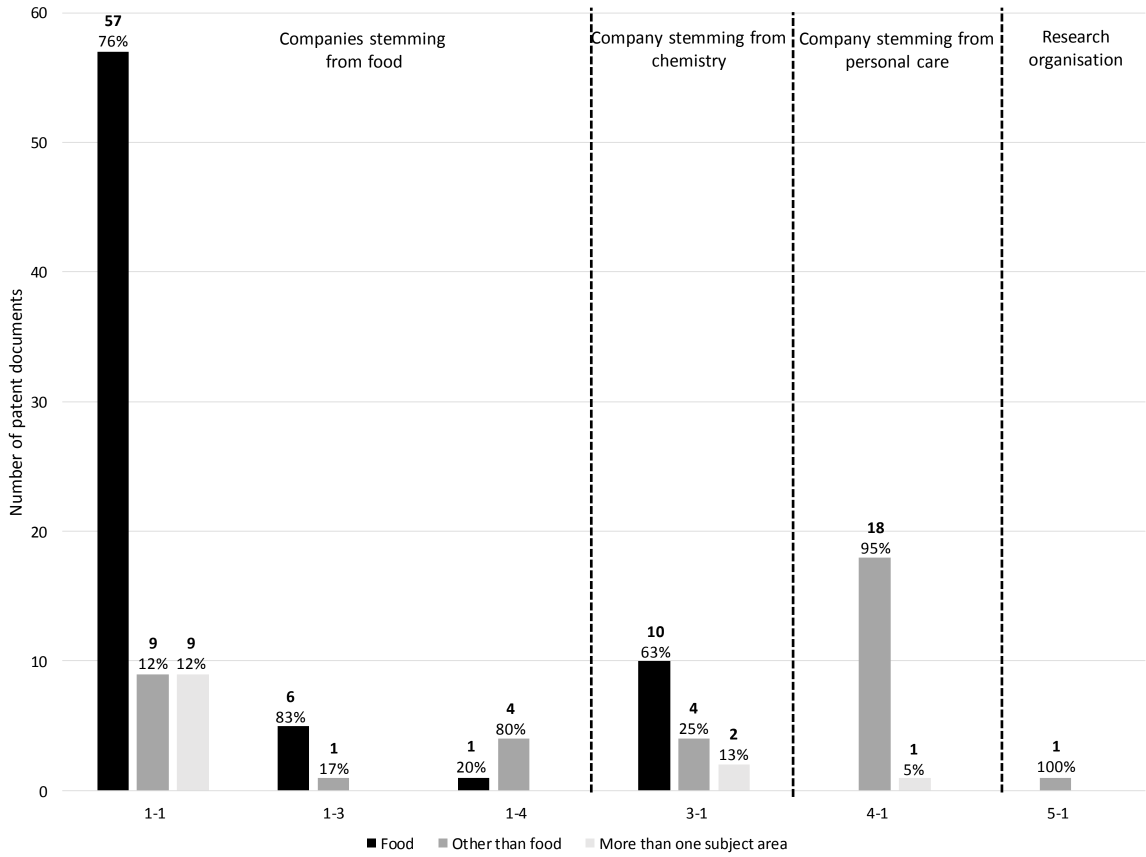



*Figure 3-8: Patent documents as a function of the patenting company and as the patent's subject area*

### 3.4.5 Regulatory convergence

The activity of applying the health claim regulation is highest among the companies from the food sector (Table 3-3). The identified health claim activities include the submission, withdrawal and resubmission of health claim applications. Collaborative health claim submissions are those that are jointly submitted by two distinct companies. Those joint applications are identified for three cases in the food, chemical and personal care sector. Concurrently, the companies involved in those joint submissions are from distinct industrial backgrounds. Thereby, one collaborative health claim submission is among 1-1 (food) and 4-1 (personal care).

Considering the health claim submissions, it can be stated that those companies active in applications are all applying for probiotics health claims, but activities for other health ingredients such as prebiotics or peptides can be also shown. These results support *P4*.

*Table 3-3: Overview of companies' activities in applying for probiotic health claims*

| Industrial background of company | Coding | Identified health claim activities | Collaborative health claim activities |
|---|---|---|---|
| ***Food*** | 1-1 | 4 | 1 |
| | 1-2 | 6 | 0 |
| | 1-3 | 0 | 0 |
| | 1-4 | 5 | 0 |
| | 1-5 | 0 | 0 |
| **Sum** | | **15** | **1** |
| ***Pharmaceutics*** | 2-1 | 0 | 0 |
| | 2-2 | 0 | 0 |
| | 2-3 | 0 | 0 |
| | 2-4 | 0 | 0 |
| | 2-5 | 0 | 0 |
| **Sum** | | **0** | **0** |
| ***Chemistry*** | 3-1 | 3 | 1 |
| **Sum** | | **3** | **1** |
| ***Personal care*** | 4-1 | 1 | 1 |
| **Sum** | | **1** | **1** |
| ***Research organisation*** | 5-1 | 0 | 0 |
| **Sum** | | **0** | **0** |

### 3.4.6 Competence convergence

Regarding the measure of mergers and acquisitions, it seems important to consider the position of the company in question as buyer or seller. As convergence related mergers and acquisitions focus on the acquirement of external assets, the present study considers only those activities in which the analysed company is in the buyer position – therefore, in the following this study focuses on acquisitions. Furthermore, this study analyses whether the acquisitions are related to convergence. Thereby, convergence related acquisitions are defined as those acquisitions that include the buyer and seller position fulfilled by two different industry sectors.

Acquisition activity is highest among those companies in the food sector (Figure 3-9). With the exception of the companies in the pharmaceutical sector, all companies from the different industrial backgrounds show activity in convergence related acquisitions. These results support *P5*.

Regarding the convergence related acquisitions, the companies in the food sector focus on the pharmaceutical sector. The chemical company is oriented towards food and pharmaceutics. Considering the convergence related acquisitions, the company from the personal care sector concentrates on the pharmaceutical sector.

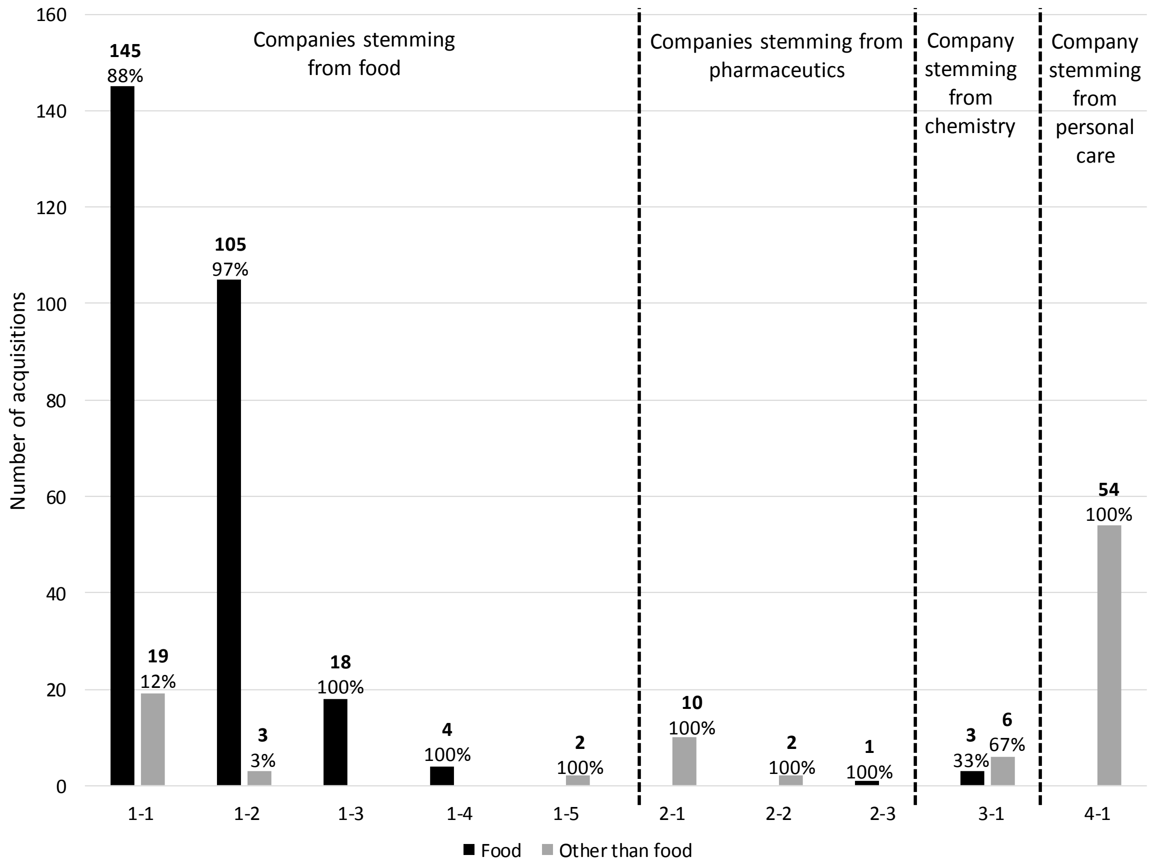



*Figure 3-9: Acquisitions as a function of the buying company and the industrial background of the acquired companies*

Regarding the measure of licenses, it seems important to consider the position of the involved company as licensor or licensee. As convergence related licenses focus on the acquirement of external assets from other industrial backgrounds, the present study considers only those activities in which the analysed company is in the licensee position. Convergence related licenses are defined as such in which the companies involved stem from distinct industrial backgrounds.

The number of licensees is highest among those companies from the food sector (Figure 3-10). In case of the food company 1-1, the licensors are come from the pharmaceutical sector in three cases, showing convergence related licenses. These results support *P5*.

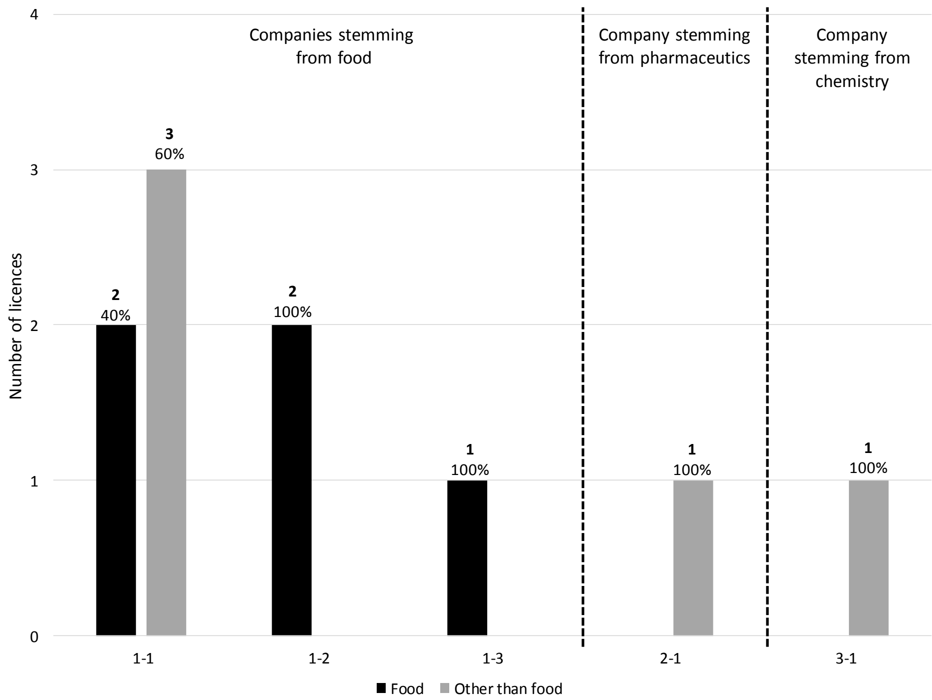



*Figure 3-10: Licenses as a function of the industrial background of the licensee and licensor*

Regarding the measure of strategic alliances, acquisitions and licenses are not considered as these actions are already examined within the two aforementioned measures. Convergence related strategic alliances are defined as those in which the partners involved have different industrial backgrounds.

The number of strategic alliances is highest among those companies from the food sector (Figure 3-11). Thereby, in all sectors convergence related strategic alliances can be shown through the involvement of distinct industrial backgrounds. These results support *P5*.

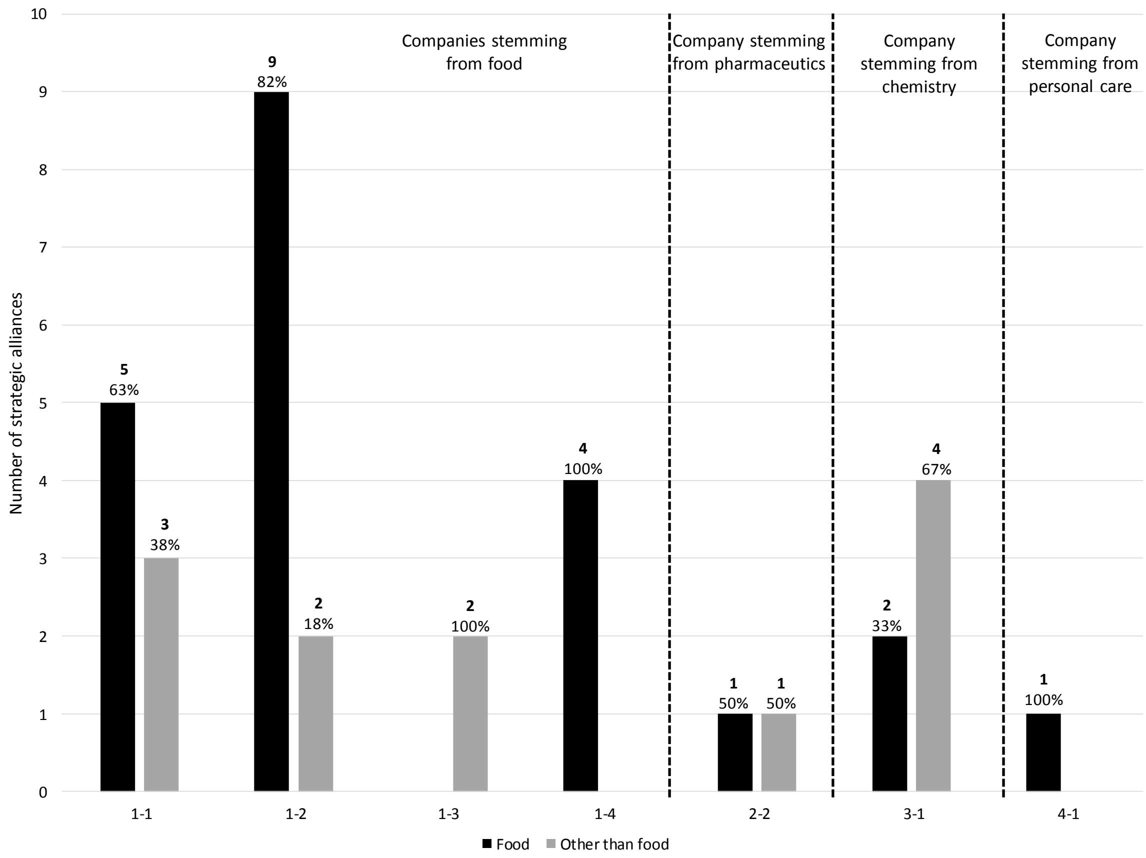



*Figure 3-11: Strategic alliances as a function of the industrial background of the involved companies*

Considering companies' characteristics, a relationship can be shown between the company's size (sales, employees) and the activity for all convergence indicators – the higher the sales/number of employees, the higher the activity. For example, the food company 1-1 shows the highest rates of scientific publications and patents among the identified companies concurrently having the highest sales and employees in the sample. This relationship between a company's characteristics and its activity in convergence related behaviour might be due to the higher research and development resources of bigger companies, which allows companies to spend more on research activities (science and technology convergence) or on acquiring external assets (competence convergence).

Summarising the results on the indicators of convergence, it can be stated that there are cross-industry relationships along the probiotics innovation value chains supporting proposition *P1*. Secondly, there are signs of science and technology convergence as the companies are publishing and patenting not only in their former industry sector but also in other sectors supporting proposition *P2* and *P3*. Thirdly, companies of the distinct industrial backgrounds show activity in obtaining approved health claims according to the European health claim regulation (EC No. 1924/2006) – so the regulation is applied by distinct industry sectors supporting proposition *P4*. Furthermore, competence convergence appears, which supports proposition *P5*.

## 3.5 Discussion

The analysis of cross-industry relationships in a context of convergence reveals that companies from distinct industrial backgrounds are active in the area of probiotics differing in their intensity of convergence related behaviour shown by the respective indicators. Therefore, this study contributes to the existing body of literature by assessing convergence from an innovation value chain perspective and combine this with a set of indicators reflecting the intensity of convergence. Those indicators have already been used and tested in literature for the description of convergence processes but have not yet been used in an overall combined analysis scrutinising the different dimensions of convergence. On-going convergence processes are discussed to lead to reconfiguration of value chains (Wirtz, 2001) and the underlying competence basis as companies try to close their emerging competence gaps. Therefore, the derived framework of indicators might serve for a landscape description of on-going convergence processes using an innovation value chain perspective.

With regard to *RQ2*, the active companies show signs of convergence related activity on all levels in probiotics. Cross-industry relationships occur in all four innovation value chains showing different positions along the innovation value chain (*P1*). Therefore, it seems that companies try to close the resulting competence gaps at different stages of the innovation value chain – depending on which stage of the innovation value chain the competence gap emerged for the company in question. Furthermore, signs of science and technology convergence can be shown for the different industry sectors involved, demonstrating convergence related behaviour in the early phases of an on-going convergence process (*P2* and *P3*). As the already converged legislation (health claim regulation) is applied by different industry sectors, signs of convergence in regulatory compliance can be identified (*P4*). This leads to the assumption that the communication to consumers through health claims seems to be an important success factor for probiotics. Competence convergence can be shown through different industrial backgrounds participating in acquisitions, licensing agreements and strategic alliances (*P5*). This might be due to the necessity of closing competence gaps by means of cross-industry relationships in the context of convergence.

In summary, the intensity of convergence differs firstly in terms of the different industrial backgrounds, and secondly in terms of the different bacteria strains. The five identified companies from the food sector show highly relevant convergence related behaviour for all indicators. However, the chemical company also shows high tendencies. The companies stemming from these two industry sectors seem to push forward the convergence process in probiotics as they show a higher intensity of activities related to convergence.

Although different indicators serve to describe the different levels of convergence, these dimensions are not detached from each other. For instance, technology and market convergence are linked to each other as technology can be developed in-house or acquired externally (Duysters and Hagedoorn, 1998) – so mergers and acquisitions are linked to both the concept of technology and market convergence as companies acquire other companies to close competence gaps on the technological level. The indicator of regulatory convergence is multifaceted as the health claim regulation as such shows convergence in regulation, for example by applying the same standards for different industry sectors. Clinical trials are mostly applied in the pharmaceutical sector to authorise drugs but are now necessary to promote nutritional products claiming a health effect.

Considering the characteristics of distinct strategic types, all three types of (a) technology developers; (b) technology-intense product developers; and (c) product developers using existing technologies (Bröring and Cloutier, 2008) can be identified in the companies analysed in this study. Based on the differences in the innovation value chains originating from convergence processes, the characteristics of these different strategic types can be defined as follows (based on the results regarding *P1-P5*).

The companies follow different strategies to close the competence gaps resulting from the on-going process of convergence. On the one hand, technology-intense product developers use all four indicators of convergence related behaviour (e.g. the two food companies 1-1 and 1-2). Therefore, they show big expansions on all levels to close their resulting competence gaps. Regarding the innovation value chain perspective, these convergence related activities and relationships also reflect the different steps within the innovation value chain. Therefore, technology-intense product developers show a high integration of cross-industry activities along the innovation value chain. On the other hand, product developers using existing technologies focus on the market side of possibilities to close their competence gaps without a focus on the technological side (e.g. the two pharmaceutical companies 2-1, 2-2). Thus, they focus on the commercialisation step within their convergence related behaviour and their position within the innovation value chain. As they hardly show tendencies of science or technology convergence related behaviour, one can assume that they try to close their competence gaps from a market driven perspective only, with no interest in the underlying technologies. Furthermore, technology developers seem to follow different strategies (e.g. the two pharmaceutical companies 2-3, 2-4). This might be due to the existing competence base in-house that results in distinct specific competence gaps, which needs to be closed differently.

**Limitations and future research**

A qualitative approach was taken to establishing the criteria for selecting the companies for this study. Although this approach cannot deliver a holistic view on all active companies in probiotics, the study in this chapter aims to select the global players in this area by choosing the bacteria strains with the highest global market share. Furthermore, the industrial backgrounds of chemistry and personal care are represented by one company for each sector. Therefore, a generalisation for the whole sector is difficult and further studies could include more companies per sector.

The period for the convergence indicators differs because of a different sampling strategy but present an overlap adequate enough to support the propositions. Considering regulatory convergence, the search strategy for health claim submissions is based on publicly available news sources, as there is no database available showing the health claim applications related to the submitting company. Therefore, the gathered information is dependent on the information strategy of each company as the companies determine what is published about their health claim submissions. The identified companies differ in their characteristics in terms of company size, market share, employees, etc. This might influence convergence related behaviour such as mergers and acquisitions, which are more likely for bigger companies due to higher budgets. Therefore, future studies could focus on the differences in cross-industry relationships between distinct company types. Based on the framework of the different indicators analysing convergence processes, further studies could concentrate on the elaboration of other emerging industry fields. It might be interesting to examine, which differences occur comparing the strategic types of industry sectors in distinct emerging fields.

# 4 Evaluation of convergence using a collaboration perspective

**Chapter 4 answers Research Question 3:**

*What kinds of cross-industry collaborations can be used to close competence gaps?*

*This chapter is based on the following publication: "BORNKESSEL, S., BRÖRING, S., OMTA, S. W. F., Cross-industry collaborations in the convergence area of functional foods. Accepted for publication in International Food and Agribusiness Management Review."*

## 4.1 Introduction

The market for foods and food ingredients has changed rapidly in recent years (Siró et al., 2008). There is a growing interest among consumers in so-called functional foods, including ingredients that may alleviate the symptoms of ageing and illness (Annunziata and Vecchio, 2011, Gray et al., 2003, Siró et al., 2008, Wong et al., 2015). Most new product launches in the functional food sector deliver new products; this is in contrast to the established food market, where most new products are only variations of existing products (Mark-Herbert, 2004). Consequently, competences from different industries (i.e. food and pharmaceutics) are required for the innovation process. Indeed, there is evidence that firms of various industrial backgrounds are active on the functional food market (Bornkessel et al., 2014, Bröring, 2005, Curran et al., 2010).

Recent literature focuses on innovations across industrial boundaries. The concept of cross-industry innovation is defined as the creative imitation and retranslation of existing solutions from one industry segment to another (Enkel and Gassmann, 2010, Gassmann et al., 2011, Hahn, 2015). Furthermore, the emergence of a new industry segment consisting of firms formerly active in different industries, leading to a blurring of boundaries between the industries is called industry convergence (see for instance Bröring, 2005, Hacklin, 2008). Both concepts are discussed as a process rather than a steady state (e.g. Curran et al., 2010, Gassmann and Sutter, 2013, Hacklin, 2008). Extant literature addresses the front end of science and technology convergence using scientific publications and patent documents (e.g. Curran et al., 2010). However, literature regarding the assessment of market and industry convergence using cross-industry collaborations is limited, especially in the emerging area at the borderline of foods and drugs leading to functional foods.

The overall aim of this paper is to analyse cross-industry collaborations in convergence leading to the functional food sector. In doing so, the determinants of cross-industry collaborations are analysed regarding the motivation and industrial scope of each identified collaboration. Using a longitudinal case study approach, this study focuses on the emerging area at the borderline of foods and drugs, where new product-market combinations such as functional foods or dietary supplements arise. The goal is to identify differences between the companies stemming from the food and pharmaceutical sectors in the employment of cross-industry collaborations.

The remainder of this chapter is structured as follows. Section 4.2 focuses on cross-industry collaborations in convergence. In doing so, the resource-based view is employed to derive the underlying dynamics of the cross-industry collaborations using the two determinants of motivation and industrial scope of the collaboration. Section 4.3 presents the sample and methods of the study. In Section 4.4, the four case studies focusing on the emerging area of functional foods are presented; the section then concludes with a cross-case comparison. Finally, the findings of the study and their implications for academics and practitioners are discussed, before the paper concludes with an outlook on future research possibilities.

## 4.2 Theoretical background: Cross-industry collaborations and their determinants in convergence

### 4.2.1 Cross-industry collaborations in convergence

Numerous recent literature sources discuss the phenomenon of innovation across industry borders (e.g. Enkel and Gassmann, 2010, Gassmann et al., 2011, Gassmann et al., 2010). General concepts such as open innovation or the innovation value chain can be discussed either within a special industry sector or across different sectors. The horizontal innovation across industry boundaries is still a challenge to manage, both in literature and in practice (Gassmann et al., 2010, Hahn, 2015). Especially in the rapidly growing functional food market, active companies have to cope with technology, market and regulatory challenges (Bröring, 2005, Wong et al., 2015). Multifaceted definitions of convergence can be found in the literature. Recent studies provide a comprehensive overview of these definitions and their different emphases (Bröring, 2005, Curran, 2010, Hacklin, 2008, Preschitschek, 2014), mainly following the common idea summarised by the Organisation for Economic Co-operation and Development as follows: *'the blurring of technical and regulatory boundaries between sectors of the economy'* (OECD, 1992).

Regarding the process perspective on convergence, one approach is the description of the consecutive steps – science, technology, market and industry – as an idealised time series of events leading to a complete convergence of two hitherto distinct industry sectors (Curran et al., 2010, Hacklin, 2008), refer also to Chapter 1.2. While the front end of the convergence process encompassing science and technology convergence is scrutinised in many recent studies using bibliometric data (e.g. Curran, 2010, Preschitschek, 2014), literature on the evaluation of the consecutive steps of market and industry convergence is rather scarce.

Literature on convergence defines market convergence as product-market combinations focusing on consumer products that combine functions and technologies of products from different industry sectors (Bröring, 2005, Curran et al., 2010, Katz, 1996, Pennings and Puranam, 2001, Stieglitz, 2004). This definition focuses mainly on the demand side of the market, whereas first measurement approaches of market convergence primarily focus on the supply side using collaborations of companies from different industrial backgrounds (Preschitschek, 2014, Sick et al., 2015). These measures of market convergence can be specified as *'cross-industry collaborations'*. With respect to the consecutive steps of convergence processes, the analysis of cross-industry collaborations seems to deliver the unifying element to analyse the junction between market and industry convergence. This analysis covers parts of both stages as cross-industry collaborations may provide a measure for the combination of functions and technologies of products from different industry sectors (market convergence) as well as the fusion of firms or industry segments (industry convergence). Thus, this chapter focuses on the later stages of convergence, encompassing market and industry convergence.

The emergent market during convergence implies a vulnerable strategic position of the involved companies due to the difficult market situation of competitors stemming from different industry sectors. In the context of the resource-based view (RBV, originated in Penrose, 1959), this vulnerable strategic position triggers companies to join collaborations in order to gain critical resources and competences that enable companies to share costs and risks (Das and Teng, 2000, Eisenhardt and Schoonhoven, 1996, Parmigiani and Rivera-Santos, 2011). As resources and competences differ between industry sectors (Penrose, 1959), these are complementary (Das and Teng, 2000). This might lead to competence gaps as the involved companies have to stretch their resources to serve the adjacent industry (Pennings and Puranam, 2001). In order to save scarce resources, the cross-industry collaborations may show a high level of competence complementarity to take advantage of the distinct core competences (Batterink, 2009, Garbade, 2014). In analysing convergence, recent literature uses strategic alliances, joint ventures, and mergers and acquisitions to operationalise market convergence (Preschitschek, 2014, Sick et al., 2015). In addition, licensing agreements are discussed in the context of convergence processes (Bornkessel et al., 2014), refer also to the study in Chapter 3.

*Licensing agreements* encompass the contract between two companies about selling the rights to use resources and competences against payment of a licensing fee (Gallini and Winter, 1985). The licensor possesses resources and competences, such as inventions or designs, that the licensee lacks (Parmigiani and Rivera-Santos, 2011). Various definitions of *strategic alliances* can be found in the extant literature about the phenomenon of collaborations between different partners. As the broad definition leads to an overlapping of the meaning of strategic alliances with other collaboration forms, this study concentrates on a narrower perspective and defines strategic alliances as follows: formal agreements between two partners, which key attribute is to exist for a set time and task (Parmigiani and Rivera-Santos, 2011). In the context of the RBV, strategic alliances are used if resources and competences for the development are owned by different companies and cannot be separated from the involved companies (Das and Teng, 2000, Madhok, 1997). Thus, strategic alliances deliver platforms of learning whereas the transfer of resources and competences is intricate (Parmigiani and Rivera-Santos, 2011). The collaboration type of a *joint venture* is defined as the creation of a jointly-owned entity by two companies that stay separate, resulting in risks and rewards for each company (Contractor and Lorange, 2002, Parmigiani and Rivera-Santos, 2011). Regarding the RBV, the used resources and competences of the two companies merge in a joint venture. Based on the definition of *mergers and acquisitions* encompassing the fusion of companies (Hennart and Reddy, 1997), the resources and the competences of the involved companies completely merge.

### 4.2.2 Determinants of cross-industry collaborations in convergence

Two main determinants can be used to analyse collaborations in convergence: the motivation and the industrial scope of the collaboration.[7]

Overall, companies join alliances to gain a competitive advantage (e.g. Lavie, 2006). Besides this general aim, the exploration and exploitation model of organisational learning (based on March, 1991) can be applied to analyse different collaboration forms based on the underlying motives and thus to identify the **motivation of a collaboration**. On the one hand, exploration collaborations aim to explore new opportunities while, on the other hand, exploitation collaborations aim to execute existing knowledge (Koza and Lewin, 1998, March, 1991, Rothaermel and Deeds, 2004). Thus exploration collaborations focus on longer-term competitive advantage, whereas exploitation collaborations concentrate on short-term commercialisation. The two traits *focus of collaboration* and *type of interdependency* based on the framework introduced by Parmigiani and Rivera-Santos (Parmigiani and Rivera-Santos, 2011) can be used in order to analyse whether the cross-industry collaborations are of an exploration or exploitation nature. First, the *focus of collaboration* relies on the general distinction between gathering new knowledge and relying on existing knowledge. While exploration collaborations aim to create new knowledge, exploitation collaborations aim to execute existing knowledge (March, 1991, Parmigiani and Rivera-Santos, 2011, Rothaermel and Deeds, 2004). Thus a collaboration focusing on exploration is characterised by extensive research with the aim of making new discoveries, while an exploitation collaboration utilises existing resources and competences (Rothaermel and Deeds, 2004). The second trait is the *type of interdependence* in collaborations, which focuses on the intensity of cooperation. While the exploration collaboration encompasses a joint development using resources and competences from both partners (reciprocal interdependence), the exploitation collaboration shows a discrete interdependence with decisions made independently by the partners (Parmigiani and Rivera-Santos, 2011).

The second determinant of **industrial scope of the collaboration** focuses on the involvement of different industry sectors. In the context of convergence with partners from different industrial backgrounds, the collaboration may encompass either resources and competences from one industry sector or from both involved industry sectors. While opening up across industrial borders, the distinction between three process forms (based on open innovation approach, ref. e.g. Enkel et al., 2009) can be made: the outside-in, inside-out and coupled processes. Relating the general approach to converging industries, the outside-in process encompasses the integration of resources and competences from other industry sectors (e.g. a company being a licensee) while the inside-out process focuses on the externalisation of assets towards other industry sectors (e.g. a company being a licensor). The coupled process incorporates both the internalisation of external assets as well as the externalisation of internal assets. This leads to the following four categories to consider in analysing

[7] Please refer to Table A-1 in the Appendix 1 for an overview of the used terminology.

the industrial scope of the collaboration: (a) *within the same industry* or (b) following an *outside-in* or (c) *inside-out* or (d) *coupled process* across industrial borders.

Beyond this theoretical background, the study at hand aims to deliver a framework with which to assess convergence based on cross-industry collaborations in the emerging area of functional foods. This leads to the following research question:

*RQ3 What kinds of cross-industry collaborations can be used to close competence gaps?*

### 4.2.3 Research framework

Although literature about the evaluation of market and industry convergence is limited, a case study on market convergence in the biofuel sector (Preschitschek, 2014) and one in the field of stationary energy storage systems (Sick et al., 2015) were recently published. There is also little literature on the emerging sector of functional foods. The convergence process is considered to be either substitutive (leading to industry fusion) or complementary (leading to a new value chain between the old ones) (e.g. Bröring and Cloutier, 2008). The convergence process of functional foods emerging between foods and drugs is already defined as complementary in the literature (Bröring and Cloutier, 2008). Therefore, the study in this chapter concentrates on the complementary convergence process in which a new value chain arises between the food and pharmaceutical sectors, delivering borderline products such as functional foods.

To analyse the arisen inter-industry segment, the study at hand focuses on companies that originate from either the food or the pharmaceutical sectors. After identifying their general activity in licensing agreements, strategic alliances, joint ventures, and mergers and acquisitions, the study identifies and describes cross-industry collaborations focusing on the emerging inter-industry segment over the last ten years. The aim is to depict the emergence of the inter-industry segment between the food and pharmaceutical sectors (ref. Figure 4-1). In addition, the relevant collaborations are analysed using the two above-described determinants of motivation and industrial scope of collaboration.

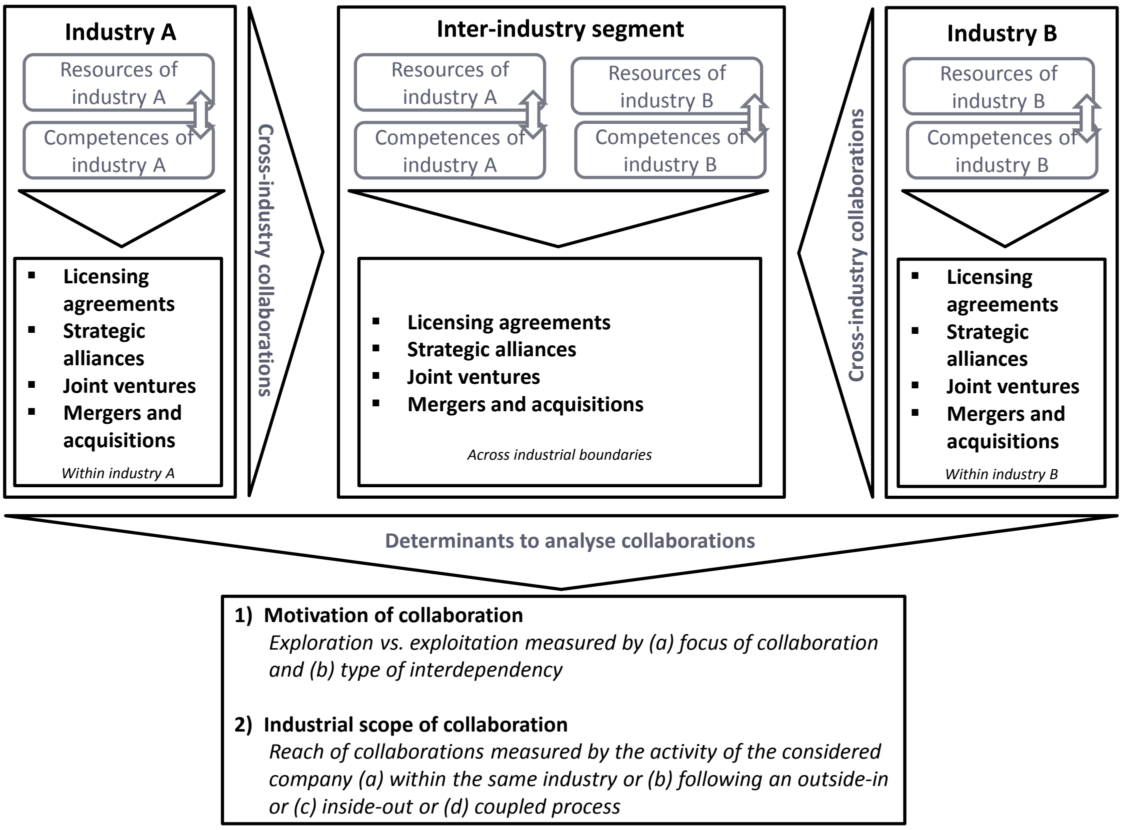



*Figure 4-1: Emergence of inter-industry segment based on the cross-industry collaborations during convergence*

## 4.3 Methods and measurement

Following an exploratory approach, the study at hand aims to answer the research question by employing a longitudinal case study focusing on the functional food sector. The case study approach is a research strategy that uses one or more cases, for instance to create theoretical constructs (Eisenhardt, 1989, Eisenhardt and Graebner, 2007). Based on different data sources, case studies contain extensive empirical descriptions of specific instances of a phenomenon (Eisenhardt and Graebner, 2007, Yin, 1997).

In order to analyse cross-industry collaborations in the convergence of the food and pharmaceutical sectors leading to borderline products such as functional foods and dietary supplements, two leading companies of each sector were selected based on market reports, websites focusing on this industry segment (e.g. *http://www.nutraingredients.com*), and scientific literature about functional foods (e.g. Bigliardi and Galati, 2013, Eussen et al., 2011, Siró et al., 2008), as well as further desk research. Sector leading companies are chosen as these are expected to show activities in the emerging inter-industry segment. In this way, the leading position was identified based on sales and market significance. The selected companies are Nestlé and Danone as representatives for the food sector and Martek and Bayer HealthCare for the pharmaceutical sector.

Following a quantitative approach using publicly available data, strategies to close competence gaps were analysed from four angles: first, mergers and acquisitions; second, licensing agreements; third, strategic alliances; and fourth, joint ventures. The identified cooperating companies were scrutinised with regard to their industrial background. The industrial background of the manufacturers was categorised according to Standard Industrial Classification (SIC) codes (U.S. Securities and Exchange Commission, 2011) available in the company profiles of the Nexis database. Based on SIC codes, the level of complementarity between the involved partners is discussed in the following results part. Cross-industry activities focusing on the emerging inter-industry segment are those in which the collaborating partners stem from different industrial backgrounds. Firstly, mergers and acquisitions were analysed using the search mask *'mergers and acquisitions'* of Nexis using each company as search term. This search mask refers to the Mergerstat M&A database, which provides detailed information on over 30 years' worth of publicly announced mergers, acquisitions and divestitures (Nexis, 2015). Secondly, using the search mask *'firm'* the identified companies were analysed considering their licensing agreements, strategic alliances and joint ventures using each company as search term. The time frame was restricted to the period from September 2005 to August 2015 as ten years show an appropriate time frame to analyse industry developments. In addition, this time frame is characterised by an increasing importance of the functional food sector (Siró et al., 2008, Wong et al., 2015).

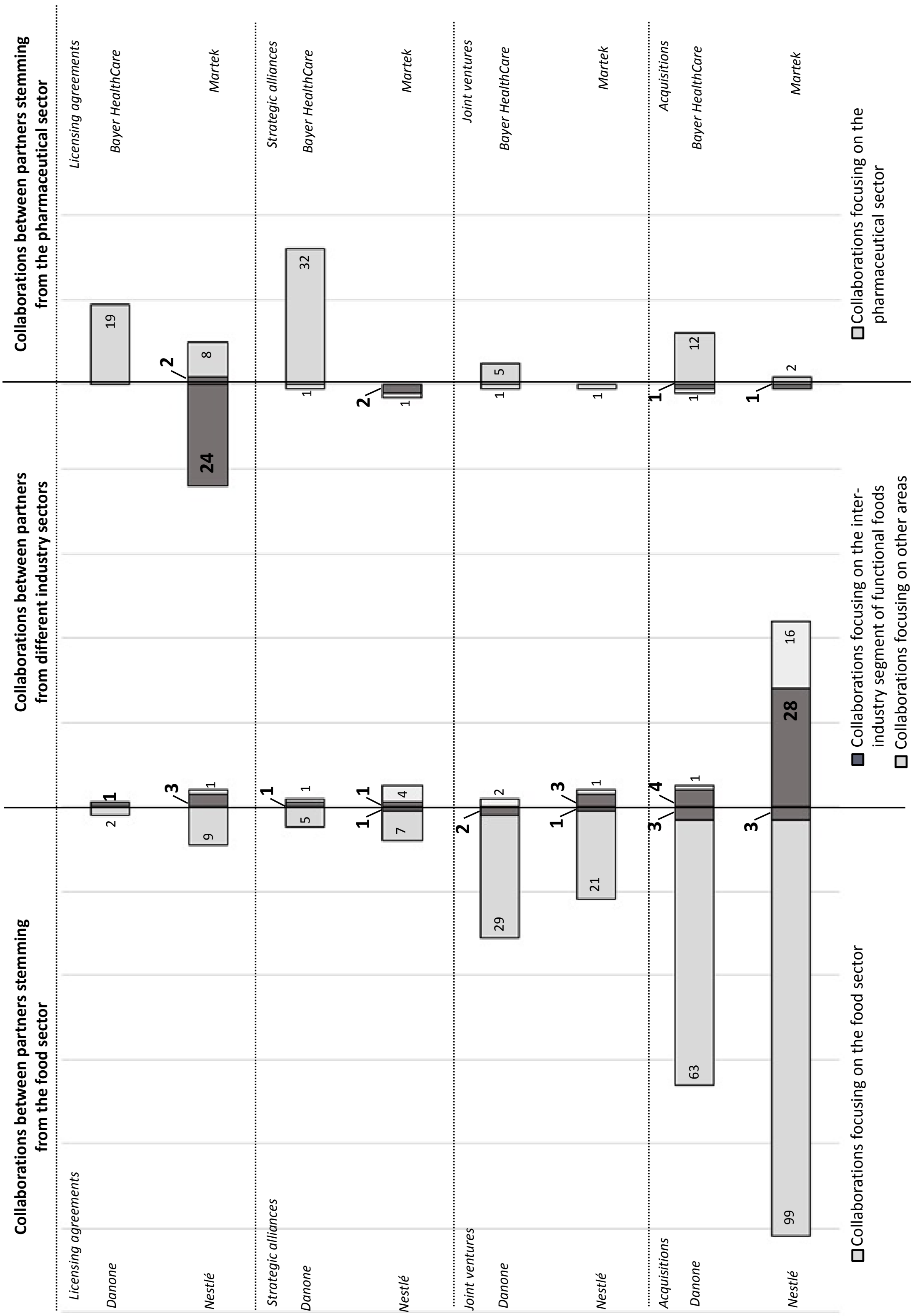
The identified cross-industry collaborations that target the emerging inter-industry segment between the food and pharmaceutical industries were analysed according to the collaboration determinants of motivation and industrial scope based on the information given in the reports. The identified collaborations were analysed with regard to their motivation (exploration vs. exploitation) by using the two measures of focus of collaboration (new knowledge vs. existing knowledge) and type of interdependency (reciprocal vs. discrete). In doing so, the collaborations were analysed with regard to their aim of either focusing on the generation of new knowledge, for example research on new functional ingredients, or focusing on the utilisation of already existing knowledge, thus using already explored functional ingredients in the existing product portfolio. In addition, the relationship of the two partners was analysed to distinguish between joint efforts to reach the aim (reciprocal), for instance a joint department to research a new functional ingredient; or the sole incorporation of resources and competences managed by one company (discrete), for instance using external research results in the context of the internal development process. The industrial scope was first identified based on the industrial background of the involved partners (SIC code). Second, if the companies stemmed from different industrial backgrounds, the direction of knowledge exchange across industrial borders (outside-in, inside-out, coupled) was determined. In the case of mergers and acquisitions, and licensing agreements, the position was considered: e.g. being a licensor shows an inside-out process and in contrast being a licensee shows an outside-in process. For joint ventures and strategic alliances, the specific agreements about knowledge exchange were considered. This categorisation scheme was applied to the evaluation of the in-depth descriptions of the considered collaborations.

## 4.4 Results

### 4.4.1 Emerging inter-industry segment

The considered companies are active in cross-industry collaborations with different degrees of intensity. Most of the collaborations focusing on the emerging inter-industry segment of functional foods are across industrial borders, thus the collaborating partners stem from different industrial backgrounds. The results show that only acquisitions can be identified in the category of mergers and acquisitions focusing on the inter-industry segment of functional foods. While the two food companies (Nestlé and Danone) focus on acquisitions within and outside their native sector, the two pharmaceutical companies (Martek Biosciences Corporation and Bayer HealthCare) put the emphasis on licensing agreements (ref. Figure 4-2). In the following part describing the four cases, only those collaborations are considered and described in-depth, focusing on the inter-industry segment of functional foods.

*Figure 4-2: Emerging inter-industry segment between the food and pharmaceutical sectors*



### 4.4.2 Cross-industry collaborations in the food sector

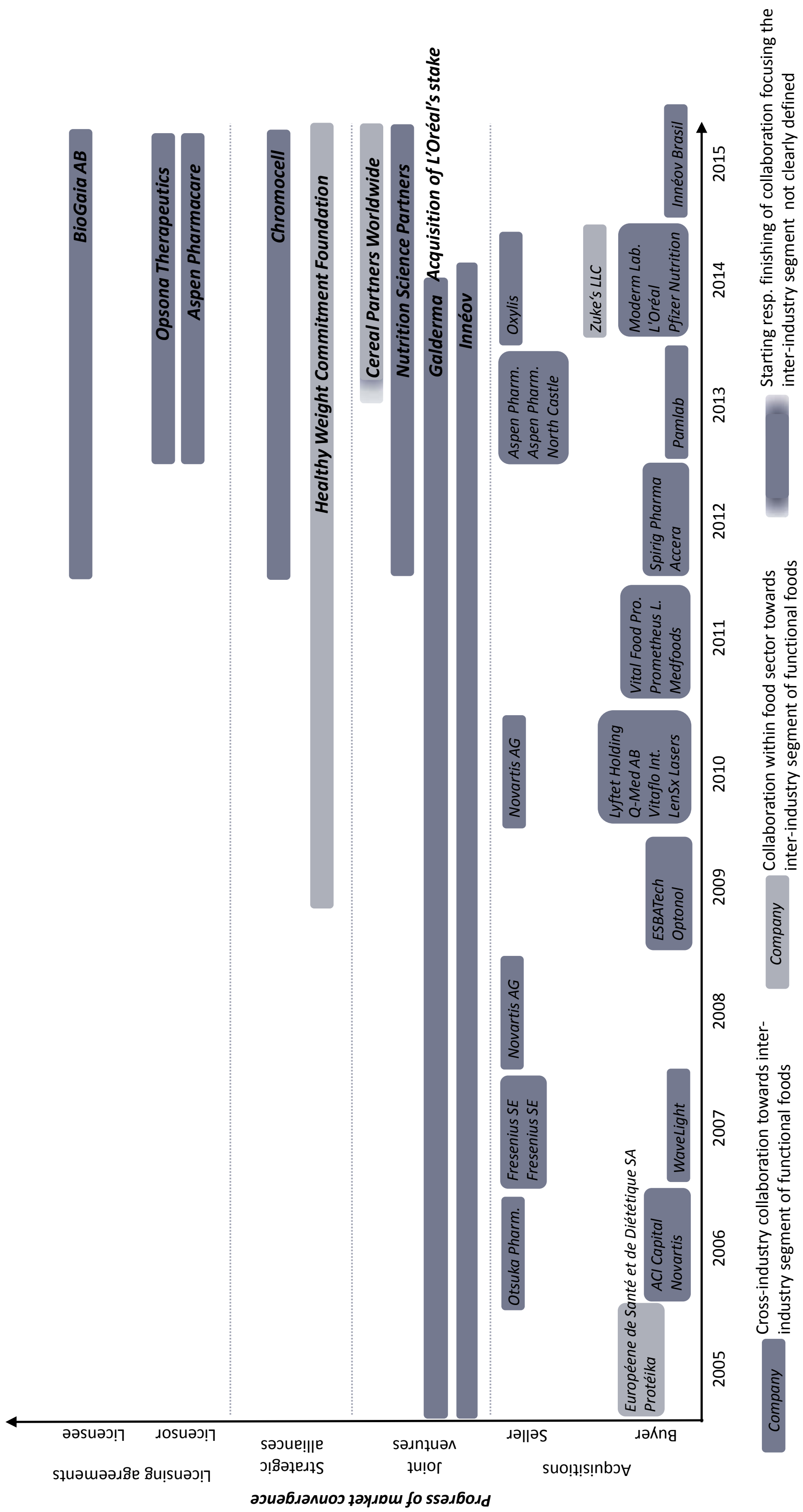
#### *4.4.2.1 Case 1: Nestlé*

The company *Nestlé* was founded in 1866 in Switzerland and has gained a worldwide significance in the food market, operating in 86 countries. While the origin of the company lies in food products, in recent years Nestlé's strategy has focused on a reorientation towards health and well-being, which can be also shown in the SIC categorisation including the food sector (codes beginning with 20) as well as the assignment of pharmaceutical preparations (SIC 2834). Nestlé's product portfolio covers a wide range of consumer food products, which are mostly marketed via brands. Key products include baby food, bottled water, cereals, chocolate, coffee, dairy products, and chilled and frozen foods. The company also shows activity in more specialised offerings, including weight management products and healthcare nutrition. Furthermore, Nestlé's healthcare nutrition portfolio ranges from supplements for athletic healthy persons to nutritional formulas for the recovery of patients. This product portfolio shows a high diversification in borderline products in the inter-industry segment between food and pharmaceutics.

**Chronological development**

Overall, the amount of cross-industry collaborations focusing on the inter-industry segment of functional foods increased during the last ten years (ref. Figure 3).

*Figure 4-3: Chronological development of Nestlé's cross-industry collaborations focusing on the inter-industry segment of functional foods in the last ten years*



The three licensing agreements that focus on the inter-industry segment of functional foods are between partners stemming from different industrial backgrounds. In two of three licensing agreements, Nestlé is in the licensor position, thus showing an inside-out process. In 2013, Aspen Pharmacare acquired licenses for several of Nestlé's products. In the same year, Opsona Therapeutics entered into a licensing agreement for a novel pre-clinical soluble protein. Furthermore, Nestlé uses a certain probiotic strain under the license of BioGaia for its functional food product portfolio, reflecting an outside-in process. These licenses show an exploitation collaboration, as the resources and competences are not used for research but for the integration into products, and there is no joint development.

Two strategic alliances target the inter-industry segment of functional foods. First, in 2009 Nestlé joined the Healthy Weight Commitment Foundation, the aim of which is to provide tools to help consumers achieve energy balance. Since this consortium of more than 40 retailers and food and beverages manufacturers delivers a communication platform to consumers, the focus of collaboration is existing knowledge and the type of interdependency is discrete, thus resulting in an exploitation collaboration. This alliance is within the food sector. In 2012, a collaborative agreement between Nestlé and Chromocell Corporation was established to identify compounds with potential taste-giving ingredients. This strategic alliance constitutes an exploration collaboration because its aim is to discover new knowledge, and because the relationship between the partners is reciprocal. The reciprocal interdependency implies a coupled process between the food and the pharmaceutical company.

Four joint ventures focus on the inter-industry segment between the food and pharmaceutical sectors. Although the two joint ventures between Nestlé and L'Oréal (Innéov, founded in 2002 and Galderma, founded in 1981) are between a food and personal care company, the inter-industry segment of functional foods is addressed. First, Innéov has launched a wide product range in the area of dietary supplements focusing on nutricosmetic health, for example targeting gastrointestinal health with probiotic products. This joint venture is an exploration collaboration that focuses on a coupled process across industrial boundaries since both companies focus on joint research (new knowledge and reciprocal interdependency). The same applies to the second joint venture, namely Galderma, which delivers products for skincare. To enter the nutraceutical market, Nestlé's subsidiary Galderma signed an agreement for the acquisitions of certain assets of the Innéov Group, since the joint venture Innéov between L'Oréal and Nestlé was terminated in 2014. The third joint venture, called Nutrition Science Partners, was established in 2012 between Nestlé and Chi-med, a pharmaceutical company focusing on traditional Chinese medicine, to develop products for gastrointestinal health, as well as for metabolic disorders and brain health in the future. Due to the joint development across industrial borders, this joint venture follows the motivation of an exploration collaboration with a coupled process. Finally, the fourth joint venture is within the food industry between General Mills and Nestlé: the Cereal Partners Worldwide. From 2014, this joint venture expanded its product portfolio to gluten-free corn flakes, thus targeting the functional food market. Due to joint research and consecutive launches, the joint venture shows an exploration collaboration form within the food sector.

Altogether, 19 acquisitions of pharmaceutically based companies can be identified in the last ten years; they all show an outside-in process due to Nestlé's integration of resources and competences from the pharmaceutical sector. Especially starting in 2009, the activity in acquisitions seems to have increased. In general, these acquisitions aim to improve the research of the formerly distinct companies, thus focusing on new knowledge based on reciprocal relationships (exploration collaboration). Three acquisitions by Nestlé of food companies also focus on the arisen inter-industry segment due to the integration of resources and competences in order to develop functional foods, thus showing an exploration collaboration process. Since Nestlé also sells divisions to pharmaceutical companies (9 transactions), Nestlé shows inside-out processes that focus on the externalisation of internal assets, resulting in research activities using these resources and competences (exploration collaboration).

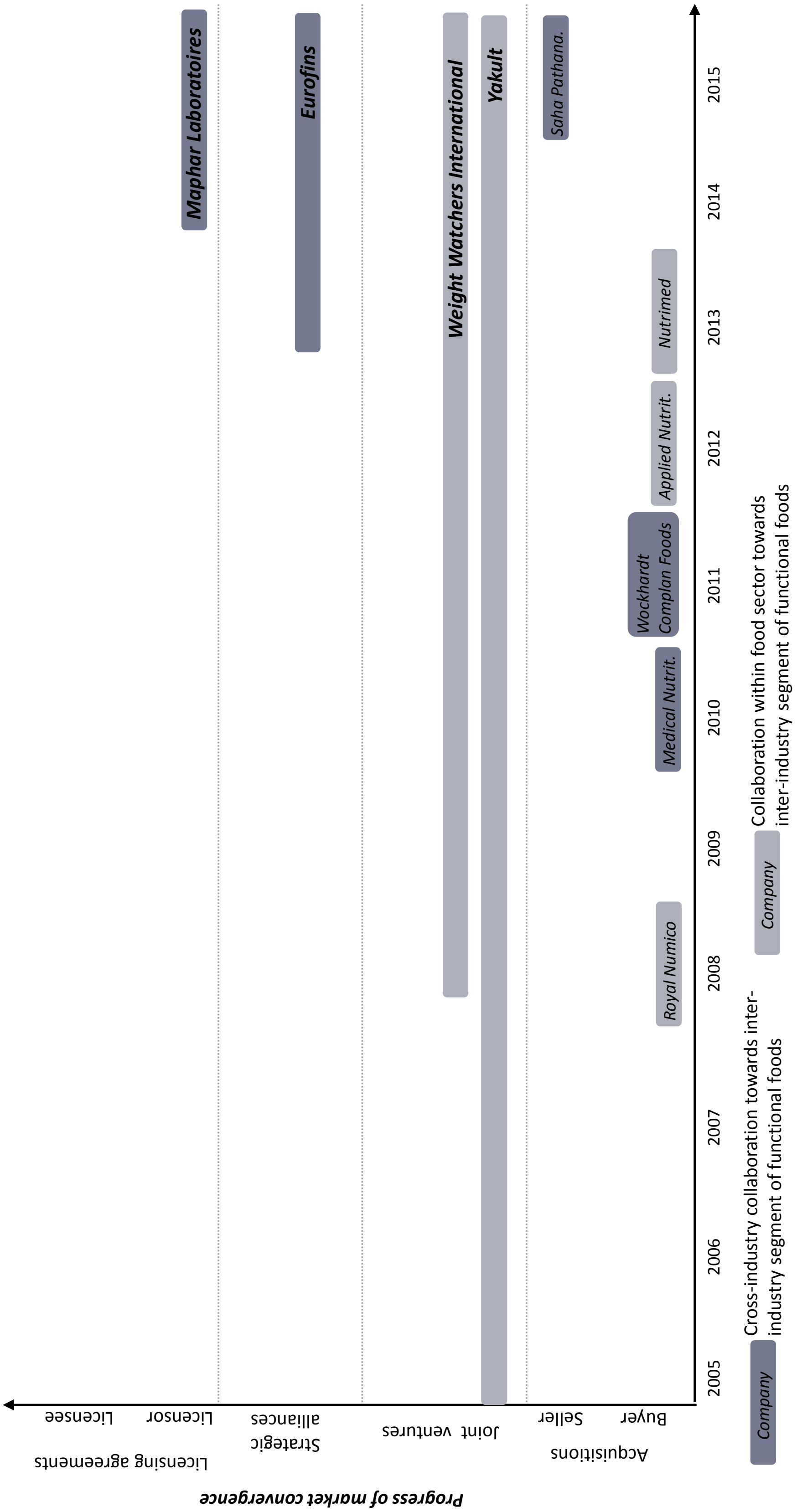
#### *4.4.2.2 Case 2: Danone*

*Danone* was founded in 1919 and strengthened its position through several mergers and acquisitions leading to today's Groupe Danone S.A., which has a leading position in dairy and water products worldwide and operates in more than 140 countries. Its SIC categorisation includes the food sector (codes beginning with 20) as well as the assignment of pharmaceutical preparations (SIC 2834), which shows Danone's orientation towards the health sector. Danone's product portfolio encompasses dairy products and in particular probiotic products that deliver an additional health benefit beyond their nutritional value. As market leader in the probiotic sector, Danone shows its strength in borderline products rising between food and pharmaceutics. Their probiotic products are in the form of traditional food products, thus showing a small distance from the traditional food sector in contrast with more specialised products such as formula nutrition in the area of medical nutrition. However, concurrently Danone is also active in the medical nutrition area and delivers nutritional formulas for patients suffering from distinct diseases.

**Chronological development**

Overall, Danone's activity in cross-industry collaborations focusing on the pharmaceutical sector is lower than that of Nestlé.

*Figure 4-4: Chronological development of Danone's cross-industry collaborations focusing on the inter-industry segment of functional foods in the last ten years*



Maphar Laboratories manufacture dietetic products under the licence of Danone. Thus, Danone shows an inside-out process towards the pharmaceutical sector. While the resources and competences are not integrated into the research process, the form of the collaboration is exploitation.

The strategic alliance between Danone and Eurofins encompasses on the one hand the acquisition of several of Danone's laboratories, and on the other hand an exclusive supplier contract for all infant nutrition analyses, thus reflecting a coupled process between the industry sectors. The focus of the collaboration is on already existing knowledge, and the relationship is discrete because for the different areas the companies stay separate. Thus, this collaboration is in the form of an exploitation.

In 2005, a joint venture between the two food companies Danone and Yakult was formed to manufacture and launch probiotic products, thus functional foods. This joint venture shows the characteristics of an exploitation collaboration, as the aim is to use the existing knowledge to gather advantages in selling the products. In 2008, a joint venture between Danone and Weight Watchers International was formed in order to establish a weight management business in China focusing on dietary changes to improve health. The two companies stem from the food sector. Since this joint venture delivers a communication platform, the focus of the collaboration is on existing knowledge and the type of interdependency is discrete, thus resulting in an exploitation collaboration.

Three acquisitions of pharmaceutical companies in 2010 and 2011 focus on the inter-industry segment of functional foods, acquiring expertise especially in the area of nutritional supplements and showing an outside-in process by Danone. The motivation of collaboration is exploration due to the incorporation of external resources and competences. On the other hand, Danone makes use of an inside-out process focusing on the externalisation of internal assets, which results in research activities using these resources and competences (exploration collaboration) while selling a division to a pharmaceutical company. In addition, three acquisitions of food companies by Danone focus on the inter-industry segment of functional foods while the motivation of these collaborations is exploration due to their incorporation of external resources and competences.

### 4.4.3 Cross-industry collaborations in the pharmaceutical sector

#### *4.4.3.1 Case 3: Bayer HealthCare*

*Bayer Healthcare* is a subsidiary of Bayer AG, which was founded in 1863. While the roots of the company lie in the chemical sector, its first pharmaceutical product was launched in 1880. Bayer HealthCare became an independent legal entity in 2003. Today, Bayer HealthCare focuses on the development and manufacturing of health care products for humans and animals. Based on the SIC categorisation, Bayer HealthCare belongs to the pharmaceutical sector (SIC 2834). Bayer HealthCare's product portfolio mainly focuses on over-the-counter (OTC) drugs. Nevertheless, Bayer HealthCare launches also consumer products focusing on the inter-industry segment between the food and pharmaceutical sectors; for example, in 1940 it launched the first multivitamin supplement in the US market. Today its brand 'One A Day®' in particular addresses the growing market segment of nutritional supplements.

**Chronological development**

Although Bayer Healthcare has strong collaborations within its sector encompassing several research agreements with universities as well as research centres, its cross-industry joint ventures and strategic alliances are only oriented towards the technical part of the health care sector and do not focus on the food market.

Bayer HealthCare's cross-industry activities in the food sector are confined to a single acquisition in 2012. With this acquisition, Bayer HealthCare internalised the expertise of manufacturing nutritional supplements of Schiff Nutrition International, thus showing an outside-in process. The motivation of collaboration is exploration due to the incorporation of external resources and competences.

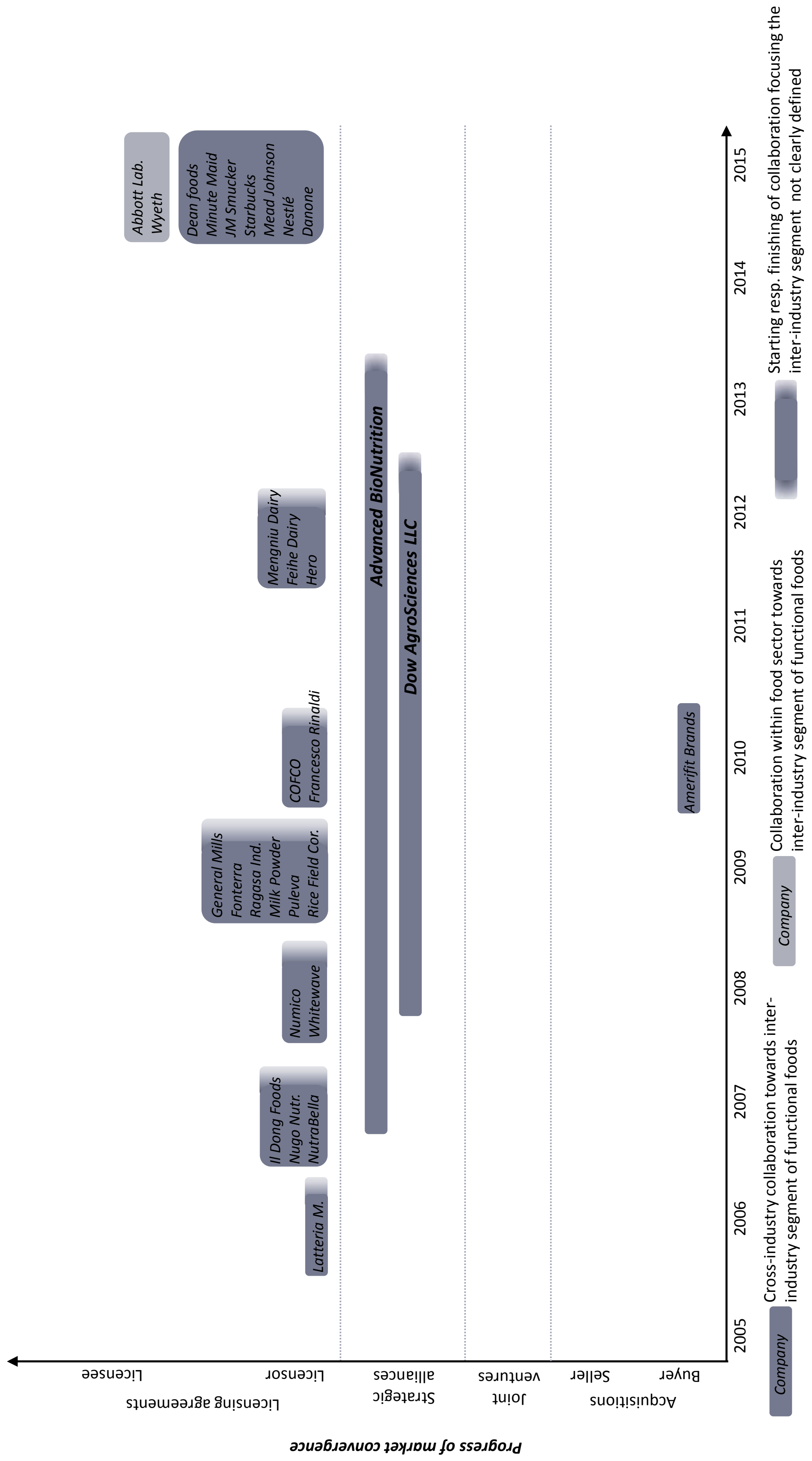
#### *4.4.3.2 Case 4: Martek Biosciences Corporation*

Founded in 1985, *Martek Biosciences Corporation* (henceforth referred to as *'Martek'*) is a subsidiary of Royal DSM and has a market presence in over 49 countries through its parent company. Based on the categorisation of the SIC, Martek belongs to the pharmaceutical sector because its SIC codes begin with 283, indicating *'drugs'*. Martek's development focuses on nutritional oils from microalgae and fungi, which are used in regular foods and beverages as well as in specialised nutrition such as infant formula, and pregnancy and nursing products. The products are sold directly as well as through distributors, since Martek is a main ingredient supplier. The company's product portfolio focuses on omega-3-fatty acids, since Martek is the major supplier of docosahexaenoic acid (DHA) used in infant formula in the US. From a global perspective, its products are used in about 75% of infant formulas. The ingredients are marketed as brands in the B2B sector. Regarding the level of complementarity, the described product portfolio is directly linked to the pharmaceutical sector. At first glance, Martek keeps its products in its traditional sector. Reviewing the licensed consumer products, however, the main usage of the ingredients developed and produced by Martek lies in the fortification of food products mainly implemented by the food sector. Furthermore, dietary supplements and prescription supplements are developed through the supply and licensing agreements between Martek and pharmaceutical or food companies. With regard to the level of complementarity, the application of the ingredients in food products leading to functional (fortified) foods and dietary supplements shows a large distance.

**Chronological development**

Overall, cross-industry collaborations in which the involved partners stem from different industrial backgrounds can be shown. Martek shows a strong position in licensing its developed ingredients for the food sector using the strong consumer and market competences of that sector to launch its products. Although Martek is not involved in joint ventures with the food sector, strategic alliances with companies from the food sector can be shown in their early phases.

*Figure 4-5: Chronological development of Martek's cross-industry collaborations focusing on the inter-industry segment of functional foods in the last ten years*



Overall, Martek is a strong licensor of omega-3-fatty acids, as the company is the major ingredient supplier of DHA for infant formula. In all identified licensing agreements Martek is in the licensor position. The food sector is the dominant licensee of ingredients from Martek, thus making use of an inside-out process. The motivation of these collaborations lies in the usage of existing knowledge (exploitation). Martek also licenses its ingredients to two pharmaceutical companies that focus on the functional nutrition market while delivering fortified baby nutrition. Again, the motivation of these licensing agreements is the usage of existing knowledge (exploitation).

In 2008, a collaborative agreement between Dow AgroSciences and Martek was formed to jointly develop and commercialise a canola seed that produces DHA. The DHA-rich canola oil is aimed at the food industry, thus showing a coupled process between the food and pharmaceutical sectors. This joint development indicates an exploration collaboration. In 2007, Martek entered into an agreement with Advanced BioNutrition Corporation showing activities in the food and the pharmaceutical sectors for the exclusive sale of DHA into the animal health market. In return, Martek became the licensee for certain technologies by Advanced BioNutrition Corporation, thus reflecting a coupled process between the food and pharmaceutical sectors. The focus of the collaboration is on already existing knowledge while the relationship is discrete since for the different areas the companies remain separate. Thus, this collaboration is in the form of an exploitation.

In 2010, Martek acquired Amerifit Brands Inc from Charterhouse Group Inc. As Amerifit has an advanced sales and marketing infrastructure and a proven management team for selling brands' branded consumer health and wellness products, Martek may close possible competence gaps in the commercialisation of consumer products, using an outside-in process. The internalisation of these resources and competences to be implemented in the company's own process shows an exploration motivation.

### 4.4.4 Case comparison

Nestlé shows the highest intensity in cross-industry collaborations, possibly due to the overall company size. As a result, the product portfolio shows a wide range of borderline products such as healthcare nutrition. The second food company considered in this study, Danone, shows a lower intensity of cross-industry collaborations than Nestlé. Nevertheless, the product portfolio including medical nutrition, for example, shows a high degree of convergence between the food and pharmaceutical sectors. The overall amount of cross-industry collaborations of the two discussed pharmaceutical companies, Bayer HealthCare and Martek, is lower than that of the food companies. Bayer HealthCare for instance focuses its research and development on the pharmaceutical sector and shows various collaborations with other pharmaceutical companies.

With regard to the different types of collaborations, the incorporation of resources and competences of the partnering companies, and thus the level of integration, differs between the collaboration forms as discussed in the following. The level of integration is low in licensing agreements because resources and competences are incorporated at most only to a limited degree, for instance in order to insert a functional ingredient into the already existing product (fortification). Strategic alliances also show a low level of integration of the partners, as only parts of the distinct resources and competences are used to complete the task, such as for instance jointly developing a specific borderline product. In joint ventures on the other hand, the used resources and competences of the involved companies merge due to the establishment of a new entity, thus resulting in a higher level of integration than in strategic alliances. Finally, in acquisitions the resources and the competences of the involved companies completely merge, thus showing the highest level of integration of the presented collaboration types.

With regard to the timely occurrence of different collaboration forms, the considered food companies first show activities in collaborations with a higher integration level (for instance acquisitions), followed by collaborations with a lower integration level (for instance licensing agreements). This may be due to the distance of complementary competences between the different sectors. First, collaborations of higher integration are needed to overcome the distance and for joint research. Based on this movement towards each other, in later stages the distance can also be overcome by collaborations of a lower degree of integration.

Figure 4-6 depicts the identified collaborations focusing on the inter-industry segment of functional foods according to the two determinants *motivation of collaboration* and *industrial scope of collaboration*.

***Motivation of collaboration***

| ***Industrial scope of collaboration*** | Exploration | Exploitation |
|---|---|---|
| Within the same industrial sector | **Joint ventures:** 1<br>*Nestlé (1)*<br>**Acquisitions:** 6<br>*Nestlé (3)*<br>*Danone (3)* | **Licensing agreements:** 2<br>*Martek (2)*<br>**Strategic alliances:** 1<br>*Nestlé (1)*<br>**Joint ventures:** 2<br>*Danone (2)* |
| Inside-out process | **Acquisitions:** 10<br>*Nestlé (9)*<br>*Danone (1)* | **Out-licensing:** 27<br>*Nestlé (2)*<br>*Danone (1)*<br>*Martek (24)* |
| Outside-in process | **Acquisitions:** 24<br>*Nestlé (19)*<br>*Danone (3)*<br>*Martek (1)*<br>*Bayer HealthCare (1)* | **In-licensing:** 1<br>*Nestlé (1)* |
| Coupled process | **Strategic alliances:** 2<br>*Nestlé (1)*<br>*Martek (1)*<br>**Joint ventures:** 3<br>*Nestlé (3)* | **Strategic alliances:** 2<br>*Danone (1)*<br>*Martek (1)* |

*Figure 4-6: Portfolio showing the different collaborations focusing on the inter-industry segment of functional foods according to the two determinants of motivation and industrial scope of collaboration*

The four described collaboration types occur within the same industry sector focusing on the emerging inter-industry segments of functional foods, whereas collaboration forms of lower integration are more likely to occur in case of exploitation. The exploration seems to require a higher level of integration of the involved companies.

The general characteristics of collaborations can also be shown for collaborations across industrial borders, which have to overcome a greater distance between complementary competences. If the knowledge exchange is unilateral, companies follow an inside-out or an outside-in process. Licensing agreements are used in exploitation collaborations, thus executing the already existing knowledge. Nevertheless, these collaborations have to overcome a greater knowledge distance in comparison to licensing agreements between companies from the same sector. In other words, executing the already existing knowledge requires the competence to adapt the knowledge from outside one's own industry sector into the existing process. Acquisitions occur if the collaborations show an exploration motivation, and thus focus on the generation of new knowledge. This collaboration form shows a higher integration of resources and competences of the involved companies, or industry sectors, as a more intense cooperation is needed to generate new knowledge based on a joint development process. Strategic alliances dominate the collaboration forms and follow a coupled process to execute already existing knowledge (exploitation). The companies involved in strategic alliances seem to integrate specific assets into the development process without a higher degree of overall integration, thus remaining separate as companies. In contrast, joint ventures, which show a higher level of integration due to the establishment of a joint entity, occur in a coupled process focusing on exploration. Due to the generation of new knowledge, a more intense cooperation is required as the resources and competences of distinct industry sectors indicate a higher level of competence complementarity.

## 4.5 Discussion

Cross-industry collaborations arise at the interface of the food and pharmaceutical sectors, and the companies identified in the present study seem to cope differently with the upcoming challenge of competence gaps. While the selected food companies show multifaceted cross-industry activities, the selected pharmaceutical companies seem to focus on the core competence of their home sector. As a result, the pharmaceutical companies are more active at the front end of the value chain, focusing on research and delivering their products to food companies that launch the emerging borderline products due to their higher expertise in consumer marketing.

The analysis of cross-industry collaborations of the food and pharmaceutical sectors reveals a higher intensity of the food sector in cross-industry collaborations towards the emerging inter-industry segment of functional foods. While the food sector seems to try to internalise the missing research competences, for example with joint ventures focusing on collaborative research, the pharmaceutical sector on the other hand seems to overcome its competence gap in consumer marketing strategies by selling the respective ingredients to food companies strong in consumer marketing.

Convergence can be assessed using different cross-industry collaboration forms such as strategic alliances or joint ventures, especially as with a higher number of competitors – due to the involvement of different sectors – higher rates of collaborations appear (Eisenhardt and Schoonhoven, 1996). The selected companies from the food and pharmaceutical sectors show differences in their intensity of using distinct collaboration types. Recent literature emphasises that multiple simultaneous collaborations between different companies is an ubiquitous phenomenon (Wassmer, 2010), while different forms such as strategic alliances or joint ventures occur at the same time. Borderline products arise from companies with a high intensity of cross-industry activities as well as from those showing a lower intensity. However, the food companies dominate the launch of borderline products, such as functional foods or dietary supplements, into the consumer market. This supports the classification of the food sector as being market oriented (Bröring, 2005) in contrast to the research-intensive pharmaceutical sector (Howells et al., 2008).

With regard to the occurrence of cross-industry collaboration forms targeting the inter-industry segment over time, the case study indicates a series of collaborations showing at first a high level of integration towards subsequently lower levels, thus an evolution from high level of integration to lower levels. In other words, first acquisitions, second joint ventures, third strategic alliances and fourth licensing agreements emerge. Furthermore, acquisitions and ventures are more likely to be used for collaborations focusing on exploration while in contrast strategic alliances and licensing agreements are more likely to be used for collaborations focusing on exploitation. Thus, first exploration followed by exploitation collaborations occur, supporting the results from a study in the biotechnology sector (Rothaermel and Deeds, 2004). The outcomes of the collaborations with different motivations (exploration vs. exploitation) build on each other. In other words, based on the exploration collaborations focusing on joint research and development, exploitation collaborations to launch products are more likely to occur.

Earlier studies on the comparison of exploitation and exploration collaborations indicate a more frequent occurrence of exploitation collaborations, for instance due to lower resource requirements (Koza and Lewin, 1998, Rothaermel and Deeds, 2004). In contrast, the study in this chapter shows a higher amount of exploration (46) than exploitation (35) collaborations. Because a large distance between the traditional fields has to be overcome in collaborations in converging industries, it seems that first a joint research background must be established based on extensive exploration collaborations before exploitation collaborations can be used to execute the knowledge generated in exploration collaborations.

**Concluding remarks**

The present chapter enhances the literature on evaluating convergence to analyse the rapid market changes in emerging sectors, such as the area of functional foods. Although recent scientific publications cover approaches for measuring convergence focusing on industry segments, the study at hand complements these studies while using an approach to scrutinise convergence on a company level based on the two determinants of motivation and industrial scope of collaboration.

Practical implications arise around the possibility for companies to use this research framework with publicly available data to analyse their direct competitive environment. In doing so, based on the identified collaborations, the future market fields of competitors can be determined, such as the joint venture between Nestlé and Chi-med planning products for gastrointestinal health, for example. Furthermore, new competitors from other industry sectors can be identified. In addition, possible partners for collaborations in a certain research area as well as the appropriate type of cross-industry collaboration can be chosen.

Besides the advantage of availability of the databases used in this study, internal activities that are not published are neglected. Although the study at hand may not cover all collaborations, the data set may be of a higher objectivity due to the publicly available sources. Further studies could concentrate on a concurrent analysis of using publicly available data and internal information, derived for example through expert interviews. Due to the small sample of cases, future studies could concentrate on a broader sample and could use examples from other industrial areas as well.

# 5 Evaluation of convergence using a consumer perspective

**Chapter 5 answers Research Question 4:**

*How can convergence be assessed using a consumer perspective?*

*This chapter is based on the following publication: "BORNKESSEL, S., BRÖRING, S., OMTA, S. W. F. & VAN TRIJP, H. 2014. What determines ingredient awareness of consumers? A study on ten functional food ingredients. Food quality and preference, 32, Part C, 330-339."*

## 5.1 Introduction

Consumers' awareness of functional food ingredients – ingredient awareness – is an important antecedent for nutritional knowledge as awareness is a necessary precondition for general knowledge (Peter et al., 1999). In this context, ingredient awareness encompasses consumers' familiarity with certain ingredients whereas the further steps from ingredient awareness coming to knowledge might be the understanding of the underlying health benefits of certain food ingredients, e.g. consumption of foods containing antioxidants and prevention of diseases (Ares et al., 2008b). Moreover, ingredient awareness influences consumers' perception and acceptance of functional foods (Pounis et al., 2011). In this sense, functional foods can be interpreted as the carrier for functional ingredients with certain health benefits. In summary, extant studies suggest that products containing certain ingredients will be more successful on the market if the consumer is aware of the inherent ingredients (Chen, 2011, Del Giudice and Pascucci, 2010, Vassallo et al., 2009). This is due to the insight that acceptance of functional foods will increase with a higher nutritional knowledge (Bech-Larsen et al., 2001, Krutulyte et al., 2011). Consequently, consumer acceptance is key success factor during the innovation process of functional foods (e.g. Verbeke, 2005, Weststrate et al., 2002) leading to challenges for both the food and pharmaceutical sector active in this inter-industry segment, thus a convergence area.

It seems important to distinguish between consumers' nutritional knowledge in general and the more specific perspective of ingredient awareness: On the one hand, consumers' nutritional knowledge in general can encompass multifaceted dimensions such as knowledge about diet or about calories (Scagliusi et al., 2009), but also the knowledge about the content of a certain ingredient in a food product, e.g. the fat content in milk (Harnack et al., 1997). General nutritional knowledge is important for healthy food choices as several studies show that nutritional knowledge in general is associated with dietary food choices (Parmenter et al., 2000, Pounis et al., 2011, Wansink et al., 2005) that promote health (Wardle et al., 2000). On the other hand, ingredient awareness can encompasses the sole familiarity of distinct ingredients (Bröring, 2005) as well as awareness of food sources of functional ingredients as for instance sources of dietary fibre (Ares et al., 2008a). Therefore, the term ingredient awareness delivers a specific term focusing on antecedents of knowledge about food ingredients themselves. In contrast to existing studies, the study in this chapter does not focus on the general nutritional knowledge, but take a rather specific approach. Hence, the following chapter will focus on consumers' awareness about specific health ingredients in particular: ingredient awareness. This specific approach aims to address the research gap in consumer convergence studies, which have not focused on the functional food area in particular.

Within the last decade a plethora of different functional food ingredients have been placed on the market (Ares et al., 2008a). Examples of these functional food ingredients are vitamins, minerals, antioxidants, probiotics and phytosterols (Bröring, 2005, Bröring, 2010). These ingredients differ with respect to consumer awareness and to the extent of scientific evidence. Functional food ingredients such as vitamins and minerals are well known among a wide range of consumers (Hoefkens et al., 2011), possibly due to the fact that they are the most common type of dietary supplements (Rock, 2007) and based on substantiated scientific evidence. But there are also more recently described functional food ingredients, which claim to be beneficial for nutritional and health aspects such as probiotics and phytosterols (Verhagen et al., 2010). The level of newness of scientific findings resp. limited research history may lead to a lower nutritional awareness of these more recently described ingredients (Parmenter et al., 2000).

Given the importance of ingredient awareness as an antecedent of knowledge of functional food ingredients for the innovation success in the converging area between the food and pharmaceutical industry, the aim of this study is to explore consumers' ingredient awareness and the determinants influencing it answering the following research question:

*RQ4 How can convergence be assessed using a consumer perspective?*

The remainder of this chapter is structured as follows. In Section 5.2, determinants of consumer awareness are applied to the context of ingredient awareness. Section 5.3 encompasses the sample description, the measurements and the methods of data analysis. In Section 3.4, descriptive results as well as the structural equation model are shown. Finally, the findings and their implications for academics and practitioners alike are discussed, before concluding with an outlook on future research possibilities.

## 5.2 Theoretical background: Determinants of consumer awareness

Extant literature suggests that ingredient awareness may be affected by aspects such as individual characteristics, situational, attitudinal and behavioural factors, and the use of nutrition information sources (Drichoutis et al., 2005) – in other words the individual information strategies of consumers (Ref. Figure 5-1 for an overview of the determinants and their relationship used in this study).

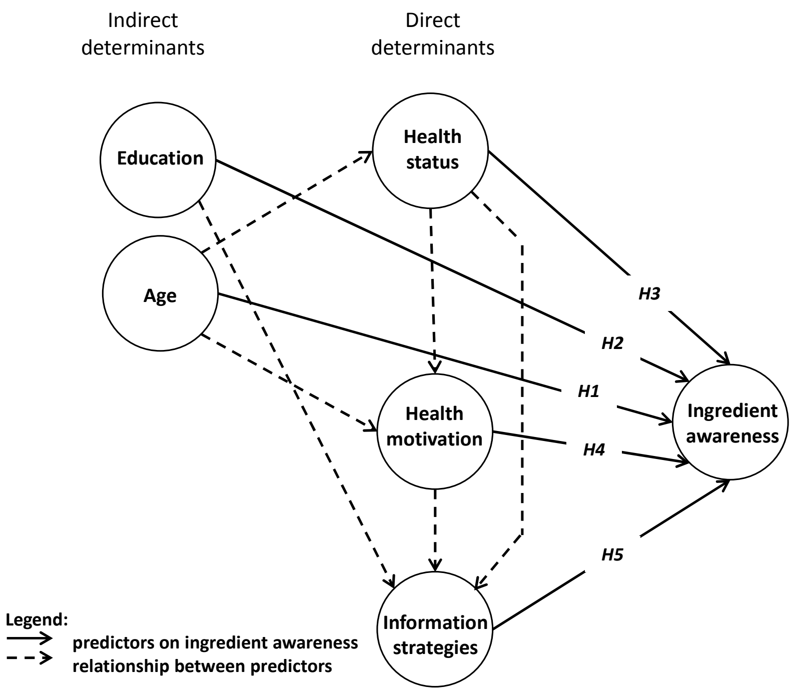



*Figure 5-1: Conceptual model showing the determinants on ingredient awareness as well as the relationship between the determinants*

The first category of individual characteristics includes inter alia socio-demographic criteria (Drichoutis et al., 2005). In this sense, it is important to consider that socio-demographic factors are not usually causal predictors themselves, but rather serve as proxies for something else (Grunert et al., 2010). With regard to the literature on nutritional knowledge, important factors seem to be consumers' age and the educational level[8] (Carrillo et al., 2012, Krystallis et al., 2008, Mowe et al., 2008).

[8] Several literature sources emphasize that the impact of gender on nutritional knowledge is dependent on the functional ingredient such as males having more knowledge on salt or sugar content while women having more knowledge on energy content (e.g. Krystallis et al., 2008, Grunert et al., 2012). As the sample consists of a wide range of distinct functional ingredients (ref. 5.3.2), different influences on the variable "ingredient awareness" are assumed. To avoid confounding, gender is not included as a determinant in the model.

In the literature, there are several ways described how age influences consumers' knowledge about nutritional aspects. Drichoutis et al. (2005) argued that with increasing age consumers have more health problems. As a result, with age diets become more restricted and nutritional knowledge and awareness as its antecedent increase (Drichoutis et al., 2005). As young consumers do not seem to be interested in health care issues, the health motivation increases with age. Young consumers' nutritional knowledge is lower than in the group of middle agers, who become increasingly aware of diseases related to diet. This leads to a higher involvement, and therefore their nutritional awareness and in consequence their knowledge increases (Parmenter et al., 2000). Against this literature background, the question arises whether the age of consumers influences also (through the above described effects) ingredient awareness leading to hypothesis 1:

H1. *The higher the age of a consumer is the higher is the ingredient awareness.*

Moreover, the socio-demographic criterion *'educational level'* seems to influence ingredient awareness (demonstrated for instance by Drichoutis et al., 2005, Parmenter et al., 2000). Thereby, education incorporates nutritional information leading to higher nutritional knowledge (Parmenter et al., 2000). Consumers with a higher educational level seem to be more acquainted with the use of several information sources such as newspapers and magazines resulting also in a higher nutritional knowledge (Parmenter et al., 2000). As more educated consumers seem to be more likely able to understand complex relationships of diet and diseases, this may also lead to a higher nutritional knowledge (Parmenter et al., 2000). Based on this discussion on the relationship between educational level and nutritional knowledge in general, the second hypothesis focusing on ingredient awareness as an antecedent of knowledge can be derived:

H2. *The higher the educational level of a consumer is the higher is the ingredient awarenes*s.

Considering the second category of determinants, namely situational factors, consumers' health status and health motivation seem to play an important role. Regarding the health status as first factor, it is evident that with a lower health status the visits to the doctor increase due to the treatment of diseases (Jürges, 2007). Therefore, the determinant health status focuses on curative aspects. During these visits the doctors as health professionals may give advice on the best way of nutrition related to the relevant disease, e.g. fat consumption and cardiovascular diseases (Tate and Cade, 1990). Consumers with a lower health status and consequently more contacts to the doctor (Jürges, 2007), are offered more detailed information on the relationship of nutrition and health (Tate and Cade, 1990). Moreover, the health status reflects the personal relevance and thus, influences consumers' involvement, which in turn may increase consumers' ingredient awareness due to the higher information search activity (Kroeber-Riel et al., 2009). This allows deducing the third hypothesis:

H3. *The lower the personal health status of a consumer is the higher is the ingredient awareness.*

The general interest in health issues leads to a specific health motivation – described for instance through the health motivation scale introduced by Jayanti and Burns (1998) including the following aspects: prevention of health problems or health hazards as well as the concern about these problems considering the own situation and the situation of related people like relatives and friends (Jayanti and Burns, 1998). In contrast to the health status, the construct of health motivation follows a preventive approach. The perceived health risk increases the more a consumer is afraid that his health is likely to suffer in the future (Drichoutis et al., 2005). Furthermore, this risk perception motivates consumers to increase their efforts in information search (Drichoutis et al., 2005). With a higher interest in health and a higher motivation regarding prevention the frequency of information usage in terms of nutritional aspects increases. A higher information usage in turn may result in a higher nutritional knowledge (Grunert et al., 2010). Subsequently, the question arises whether consumers' motivation of prevention shows an impact on consumers' awareness of health ingredients (Drescher et al., 2009, Roosen et al., 2008). This allows hypothesising:

H4. *The higher the health motivation of a consumer is the higher is the ingredient awareness.*

The third category of determinants on nutritional knowledge and possibly also ingredient awareness is consumers' information strategies. Consumers are offered a wide range of different information sources such as journals, internet, television, etc. to gather nutritional information (Max Rubner-Institut, 2008). These different media types are of a great importance for nutritional purposes (Carrillo et al., 2012) as there is an urgent need to increase awareness levels among a wide range of consumer groups (Gray et al., 2003). Therefore, the frequency of use of nutrition information sources needs to be considered. The relationship between nutritional knowledge and information usage can be seen from two angles: firstly, it is reasonable to expect that nutritional knowledge can affect information usage, but secondly, it is also possible that information usage may affect nutritional knowledge (Drichoutis et al., 2005). In this context, the fifth hypothesis considering the awareness of functional food ingredients can be derived:

H5. *The more often a consumer uses information sources for nutritional purposes the higher is the ingredient awareness.*

## 5.3 Methods and measurement

### 5.3.1 Participants

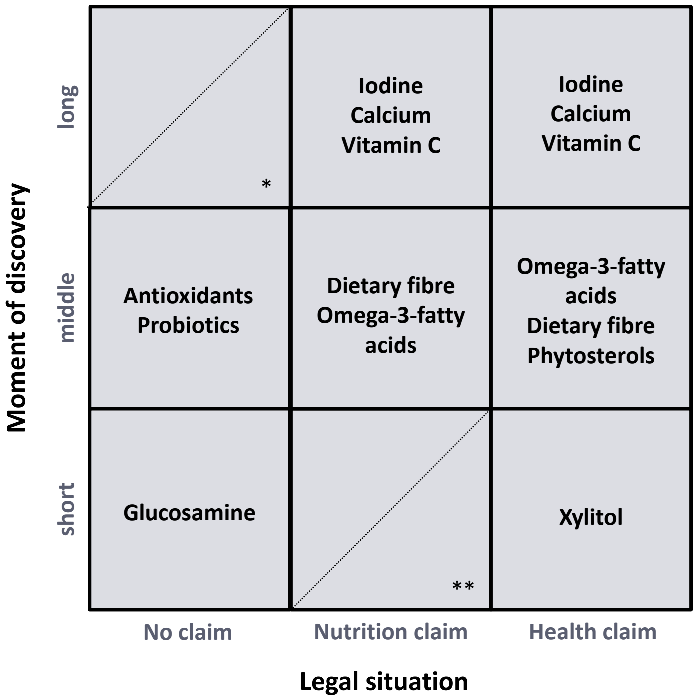
A sample of 200 German consumers was interviewed via CATI (computer aided telephone interview) during two weeks in September 2011. The interviewees have been sampled by drawing upon the ADM (Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute e.V.)-sampling-system, which provides a representative random sample of Germany. The participants were representatively selected based on the range of numbers available in the German telephone network (Von der Heyde, 2009). This available telephone data is used to generate telephone numbers – using statistical methods introduced by Gabler et al. in 1998 in order to get a representative sampling frame (Gabler et al., 1998). Due to the landline sampling, telephone numbers include a regional marker allowing stratified sampling procedures (Von der Heyde, 2009). That allows a representative sampling frame covering all German areas. Furthermore, the interviewees were chosen for a representative sample by the criteria age (18 years and older) and gender. Due to these sampling criteria, this study assumes a representative sample although the response rate was low at 7%.

### 5.3.2 Measurements

**Ingredients**

In order to derive a heterogeneous group of different ingredients available on the European market, a sample of ten functional food ingredients has been identified according to the following logic: firstly, the legal situation (more specifically the European health claim legislation) and secondly the moment of discovery. In Europe the health claim regulation (EC No 1924/2006) dealing with nutrition and health claims administers the labelling of foods and dietary supplements with additional health benefits. By now, the European Food Safety Authority (EFSA) has evaluated most of the submitted dossiers[9] and published a list of authorised and rejected nutrition and health claims. Secondly, the moment of discovery is important as it can serve as a proxy to estimate the duration of market availability, hence, market diffusion. This is because the longer the research history of an ingredient, the longer its market availability may be. This in turn might lead to a higher diffusion rate. These two criteria allowed to derive a portfolio of ten diverse ingredients as depicted in Figure 5-2.

[9] Except for the botanicals, which are not included within the examples of ingredients in the present study.




* A long research history would imply that there are enough studies to submit a claim
** For a nutritional claim scientific evidence is necessary, which should be based on a longer research history

*Figure 5-2: Portfolio showing the choice criteria*

Seven ingredients of the ten chosen are in different claim categorisation (two categories of nutritional and health claims): vitamin C, calcium, iodine, dietary fibre, phytosterols, xylitol and omega-3-fatty acids. By now (December 2015), the three remaining ingredients do not carry an authorised claim: probiotics, antioxidants and glucosamine (see Appendix 2 for an overview of the claim categorisation). The chosen ingredients differ in their moment of discovery categorised into three levels of short, middle and long (see Appendix 3 for categorisation criteria).

The categorisation leads to a matrix of nine ingredient types by differentiating the moment of discovery in short, middle and long and the legal situation in no claim, nutritional claim and health claim. As illustrated in Figure 5-2, the box describing ingredients with a long research history and no claim is empty because a long history would imply at least a nutritional claim based on generally accepted scientific evidence due to the publications made on this ingredient (claim according to Art. 13.1). Furthermore, as for a nutritional claim generally accepted scientific evidence is needed, it is not likely that an ingredient with a short research history has a claim. Nevertheless, one health claim considering xylitol – an ingredient with a rather short research history – is approved and therefore also included in this study. Based on this portfolio, the ten ingredients were chosen to cover as many ingredient types as possible.

**Measures**

Consumers' ingredient awareness was measured based on the ten chosen functional food ingredients. Consumers were asked to state whether the ingredient is unknown, little-known, known or well known to them[10] (ref. to Appendix 4). A sum score was built summing up all awareness values of the ten

[10] To minimise inter-observer variability, short explanations of the answer options were given to the consumers. For example, "well-known means high level of knowledge about the physiological function of the ingredient at hand as well as the presence in foods". The same applies to the other questions and their related answer options.

different ingredients for each consumer. In doing so, the sum score for each consumer can reach from 10 (scoring only 1 point for each ingredient) up to 40 (scoring the maximum of 4 points for each ingredient). Considering the socio-demographic criteria, age was measured in years and education on the three levels: practical education, academic education and none of them. Furthermore, the determinant health status was measured by a reflective scale based on the EQ-5D™ (EuroQol Group, 2013) using the items health status in general, physical mobility, mental well-being and self-care (ref. to Appendix 4). Sampled consumers had to assess themselves whether these items were very poor, poor, barely acceptable, good or very good. The coefficient of internal consistency Cronbach's alpha was 0.711 regarding the health status scale. The second determinant health motivation was based on the reflective scale introduced by Jayanti and Burns in 1998 focusing on aspects of prevention and health concern (for further information see Jayanti and Burns, 1998 and ref. to Appendix). Answers were given on a 5-point Likert scale reflecting the level of agreement to the statements. The coefficient of internal consistency Cronbach's alpha was 0.656 with regard the health motivation scale. The third determinant information strategies summarised within a formative scale ten different information sources (based on the National Nutrition Survey II, which is a representative study on nutritional behavior in Germany, ref.Max Rubner-Institut, 2008 and to Appendix) to elaborate the frequency of use with the following answer possibilities: never, rarely, now and then, often or very often. The coefficient of internal consistency Cronbach's alpha was 0.744 with regard to the determinant information strategies.

### 5.3.3 Data analysis

Structural equation modelling was applied to test a theoretically derived construct of hypotheses (Weiber and Mühlhaus, 2010) summarised in the measurement model (or outer model) and the structural model (or inner model) (Tenenhaus et al., 2005). The outer model includes the measures – described above. To calculate the structural equation model the variance based method was used as the model contains a formative construct to measure the information strategies. The program smart-PLS 2.0 (M3) was used for the analysis (Ringle et al., 2005). Due to the inclusion of a formative construct, an overall fit of the model cannot be calculated. Nevertheless, the relevance of prediction ($Q^2$) and the effect sizes ($f^2$) for the predictors have been determined.

Tests of mediation were analysed using the bootstrapping method. According to Baron and Kenny (1986), the three following conditions must be fulfilled for a mediating effect: firstly, there must be a significant effect of the independent variable on the dependent; secondly, the independent variable must have an effect on the mediating variable and thirdly, the mediator significantly influences the dependent variable (Baron and Kenny, 1986, Silva et al., 2010). Furthermore, an effect ratio to describe the strength of the mediation can be calculated for the mediating effect (Shrout and Bolger, 2002).

The high Cronbach's alpha for the determinant information strategies (formative construct) indicates a correlation between the different items. To avoid multicollinearity, a principal component analysis (PCA) was done with the software tool IBM SPSS statistics 20 (method described by Cohen, 2010). Another reason for using the components rather than the single items was that four items (health claim, television, radio and consumer service centre) delivered negative weights within the PLS analysis if the single items were included in the model. This again indicates for a multicollinearity between the items. The PCA was conducted based on oblimin rotation. Three factors were extracted (based on the results from the scree plot and according to Kaiser's criterion) and transferred into smartPLS. The results of the factor loadings are shown in Table 5-1 and the further results concerning the extracted communalities, eigenvalues and percentage of variance are presented in Table 5-2.

*Table 5-1: Description of components from PCA regarding information strategies*

| | Component 1 *'traditional channels'* | Component 2 *'package information'* | Component 3 *'information channels'* |
|---|---|---|---|
| **Health claim** | .069 | **.883** | -.100 |
| **Ingredient list** | .013 | **.850** | .135 |
| **Journals/ magazines** | **.727** | .065 | -.167 |
| **TV** | **.634** | .110 | .144 |
| **Radio** | **.803** | -.057 | -.009 |
| **Internet** | -.211 | .092 | **.779** |
| **Consumer services** | .345 | .091 | **.413** |
| **Public authorities** | .270 | -.190 | **.511** |
| **Recommendation by friends** | .027 | .032 | **.677** |
| **Recommendation by experts** | .432 | .086 | **.337** |

*Table 5-2: Results from PCA showing the extracted communalities, eigenvalues and the percentage of variance*

| | Extracted communalities | Eigenvalue | Percentage of variance | Cumulated percentage |
|---|---|---|---|---|
| **Health claim** | .785 | 3.105 | 31.048 | 31.048 |
| **Ingredient list** | .783 | 1.330 | 13.298 | 44.346 |
| **Journals/ magazines** | .497 | 1.077 | 10.774 | 55.119 |
| **TV** | .526 | .994 | 9.942 | 65.062 |
| **Radio** | .625 | .782 | 7.816 | 72.878 |
| **Internet** | .570 | .711 | 7.114 | 79.991 |
| **Consumer services** | .414 | .597 | 5.967 | 85.958 |
| **Public authorities** | .407 | .547 | 5.468 | 91.426 |
| **Recommendation by friends** | .479 | .508 | 5.083 | 96.510 |
| **Recommendation by experts** | .425 | .349 | 3.490 | 100.000 |

The first component considering the distinct information sources can be described by a high frequency of use of rather traditional channels such as journals or the radio – therefore, the study frames this as *'traditional channels'* for the description of the first component. The second component represented a high frequency of package information such as health claims and the ingredient list – consequently named as *'package information'*. The third component was characterised by a high frequency of use of more informal channels such as recommendation by friends and using the internet leading to the term *'informal channels'*.

## 5.4 Results

### 5.4.1 Consumers' ingredient awareness

The descriptive statistics of this study indicate that consumers' ingredient awareness varies throughout the German population (see Figure 5-3). Vitamin C and calcium were the ingredients with the highest awareness among the interviewed consumers. These two ingredients show a long research history (Biesalski and Adolph, 2010) and carry a nutritional as well as a health claim (ref. Figure 5-2). This is also the case for iodine (fourth ingredient). The two ingredients with a middle research history and a nutritional as well as a health claim – dietary fibre and omega-3-fatty acids – showed also a high awareness among a wide range of the interviewed German consumers (89% resp. 70%). Their health effects are also scientifically proven but based on more recently research (Biesalski and Adolph, 2010, DGE, 2008). The left ingredients (probiotics, antioxidants, glucosamine, phytosterols, xylitol) represented a rather heterogeneous group in case of consumer awareness, research history and legal situation. Probiotics and antioxidants were known among a smaller consumer group (36% resp. 38%), show a middle research history and, yet, carry no claim (as of December 2015). A share of 18% of the interviewed consumers were aware of glucosamine whereas glucosamine is characterised by a short research history and has no claim available. Phytosterols have a health claim available and show a middle research history, but only 6% of the interviewees were aware of them. Xylitol also does carry a health claim, does only have a short research history and was known by only 2%. The standard deviation was very high in all cases, which might be a result of heterogeneous ingredient awareness of the individual consumers.

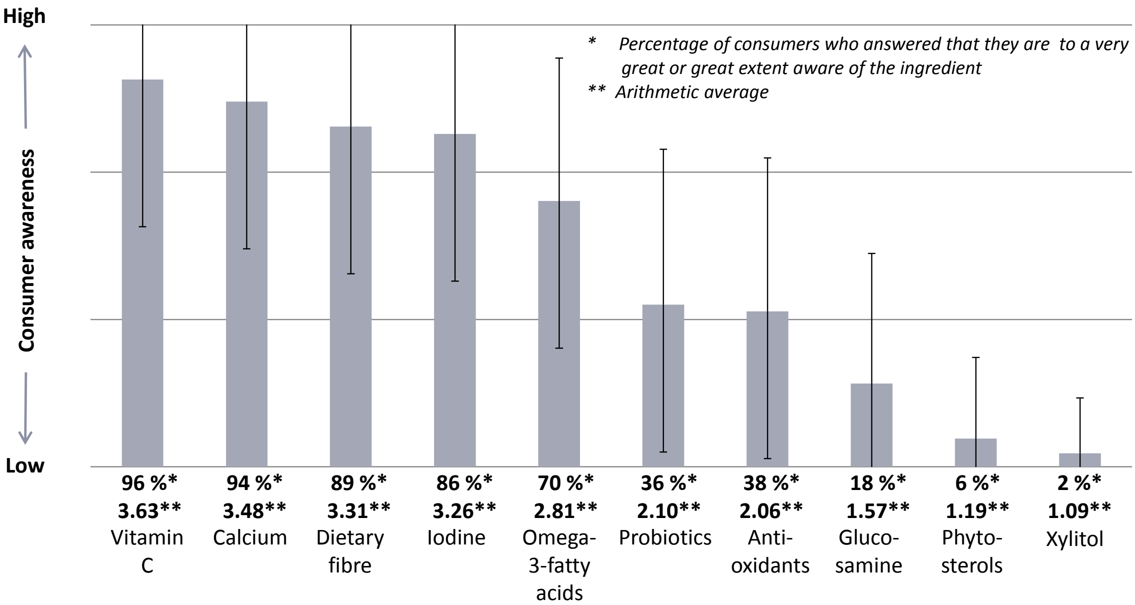



*Figure 5-3: Arithmetic average of ingredient awareness including standard deviation*

The sum score for each consumer can range from 10 (scoring only 1 point for each ingredient) up to 40 (scoring the maximum of 4 points for each ingredient). The minimum score of a consumer was exactly 10. That means the awareness of every ingredient was on the lowest level. The maximum score a consumer reached was 37 – so very close to the possible maximum. The average sum score was 24.5.

### 5.4.2 Determinants of consumers' ingredient awareness

The overall model is shown in the following figure (see Figure 5-4), which summarises the determinants on consumers' ingredient awareness as well as the relationship between them. The results from running the PLS algorithm and the bootstrapping[11] (Field, 2011) are summarised in one figure. As depicted in Figure 5-4, the results showed an overall relevance of prediction as $Q^2$ was higher than zero (value = 0.2010).

[11] Bootstrapping is '*a technique from which the sampling distribution of a statistic is estimated by taking repeated samples*' (Field, 2011).

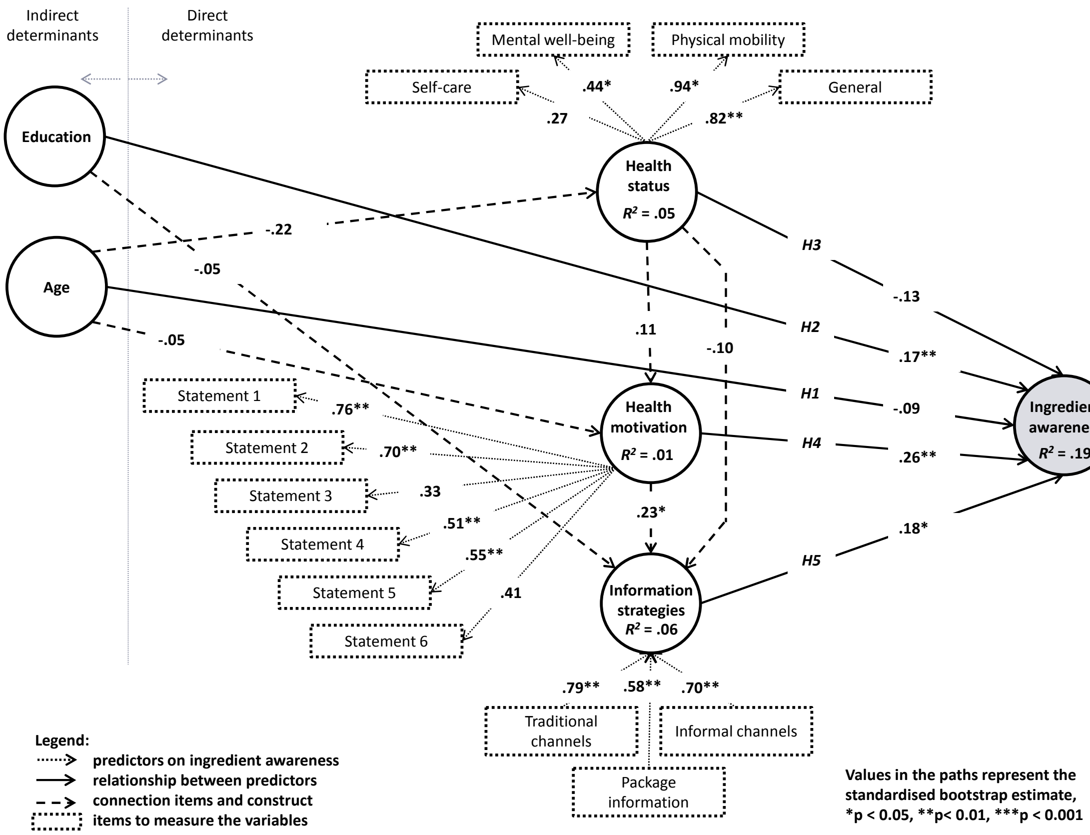



*Figure 5-4: Results of smartPLS*

To check the model in terms of multicollinearity between the different items, the variance inflation factor (VIF) was calculated. The VIF scores indicate that there were no interdependencies between the variables as the values for all considered variables were between 1.1 and 1.8.

Overall, it can be stated, that 19% ($R^2$) of consumers' ingredient awareness were explained through the described model. The effect sizes ($f^2$) of the predictors (education, health status, health motivation, information strategies) on consumers' ingredient awareness showed low influences, the effect size for the predictors age and health status did not show a relevant influence (Table 5-3).

*Table 5-3: Effect sizes ($f^2$) on ingredient awareness*

| | **Effect size $f^2$** |
|---|---|
| **Age** | 0.009 |
| **Education** | **0.032** |
| **Health status** | 0.014 |
| **Health motivation** | **0.077** |
| **Information strategies** | **0.043** |

Having a look at the single determinants, age did not have a significant influence on consumer awareness. Therefore, the results do not support the first hypothesis (H1). Furthermore, age had no significant influence on consumers' health status and no influence on the health motivation.

The educational level showed a significant impact on consumers' ingredient awareness. Thus, the data supports the second hypothesis (H2) as it states that the higher the educational level the higher is the ingredient awareness. Furthermore, there cannot be found a significant influence of the educational level on the use of information sources.

The most important direct factor was consumers' health motivation. For that reason, the results support hypothesis 4 (H4) – the higher the health motivation is the higher is consumers' ingredient awareness. Moreover, health motivation showed a significant influence on information strategies. This implies that the higher the health motivation of a consumer, the more often this consumer uses different media types to inform himself on nutritional matters.

The health status did not show a significant influence. Based on that data, the third hypothesis (H3) has to be rejected. Furthermore, the health status did neither influence health motivation nor the information strategies.

The information strategies showed a significant influence on consumers' ingredient awareness, which supports the fifth hypothesis (H5) – the higher the frequency of use of different media types for nutritional purposes, the higher is consumers' ingredient awareness.

Considering the relationship between health motivation, information strategies and ingredient awareness, a mediating effect might be possible as these relationships show significances (ref. to the requirements of identification of a mediating effect within the measures part). The indirect effect showed significance (Table 5-4). The effect ratio showed that 16 % were explained through the mediating effect (Table 5-5). Interestingly, the direct effect was higher than the total effect. That means, neglecting the additional influence of the mediating variable information strategies, the effect from health motivation on ingredient awareness increased.

*Table 5-4: Indirect effect in the structural model (results from bootstrapping)*

| **Relationship** | | **Bootstrapp estimate** |
|---|---|---|
| From | To | |
| Health motivation | Ingredient awareness | .04** |

*Note: n = 200, estimates represent 2000 bootstrapping testing.*
**p < 0.05, **p< 0.01, ***p < 0.001*

*Table 5-5: Mediating effect between health motivation, information strategies and ingredient awareness*

| **Relationship** | | **Total effect (C path)** | **Direct effect (C' path)** | **Effect ratio** |
|---|---|---|---|---|
| From | To | Estimate | Estimate | |
| Health motivation | Ingredient awareness | .26** | .31*** | .16 |

*Note: n = 200, estimates represent 2000 bootstrapping testing.*
**p < 0.05, **p< 0.01, ***p < 0.001*

## 5.5 Discussion

As shown by the present study, ingredient awareness varied throughout the sample of German consumers and was influenced by different determinants. The determinants on the level of individual characteristics, situational, attitudinal and behavioural factors, and the use of nutrition information sources were of different importance as discussed in the following. Especially as ingredient awareness and its determinants are varying throughout the population, the knowledge about consumers' awareness about certain ingredients during the innovation process enables companies from the food and pharmaceutical background to find an appropriate communication and positioning strategy for their new products.

Contrary to earlier studies (e.g. Drichoutis et al., 2005), in this study age showed no significant influence on ingredient awareness in general. This might be due to the different length of research history as the older consumers might not be able to have learned already during their basic education about the relationship of newer ingredients and their health benefits (Parmenter et al., 2000).

Our results support earlier studies stating an effect of education on nutritional knowledge in general (see for instance Carrillo et al., 2012, Mowe et al., 2008). Since the educational level showed a significant influence on ingredient awareness, an ingredient-indication relationship seems to be learned through education due to the longer research history (Parmenter et al., 2000). Furthermore, as more educated consumers are better able to understand nutritional information on packages, for instance health claims (Parmenter et al., 2000), this more accurate appraisal of health claims might have led to a higher ingredient awareness.

Although functional food ingredients are closely related to health benefits the health status did not show a significant impact on ingredient awareness. One explanation may be that the explanations given by health professionals are too complicated and this leads to a confusion of consumers (Tate and Cade, 1990). Another reason might be that with a lower health status different doctors give their opinion about nutritional aspects (Tate and Cade, 1990). This again might lead to an uncertainty of consumers resulting in lower ingredient awareness. Furthermore, it seems important to mention that the relationship between health status and ingredient is not linear but rather U-shaped. That means a very high health status as well as a very low health status is associated with a lower ingredient awareness. The lower ingredient awareness of very healthy consumers might be due to the lower personal relevance of prevention through nutrition. Consumers with a rather low health status seem to rely on their health professionals and have a lower cognitive processing resulting in a lower ingredient awareness.

Health motivation seems to be the most important determinant showing a highly significant influence on ingredient awareness. Furthermore, health motivation influenced consumers' information strategies, which in turn determined ingredient awareness. This mechanisms is also shown for instance by Grunert et al., 2010. One reason for that might be the higher involvement (Drichoutis et al., 2005).

Furthermore, the indirect effect (mediating) from information strategies showed significant results. Interestingly, the direct effect was even higher than the total effect. That implies that the use of distinct information sources for nutritional purposes (information strategies) seem to inhibit the effect from health motivation to ingredient awareness. Beyond that reasons, health motivation seems to be pivotal for ingredient awareness.

Consumers' information strategies positively influenced ingredient awareness. Therefore, a company's expenditure on advertising and therewith a high media presence might also influence consumers' ingredient awareness. The frequency of use of information sources differed between the distinct media types. In this context, a central determinant of the willingness to accept a functional food is the way consumers obtain their information and knowledge (Del Giudice and Pascucci, 2010).

Three categories of functional food ingredients can be derived. These differ with respect to certain characteristics such as scientific history, market diffusion etc. (Table 5-6). The length of research history and the legal situation were already considered as choice criteria (Figure 5-2). But the heterogeneity of the ten ingredients refers not only to these two criteria. Additionally, the ingredients differ in terms of their specificity – that means that this study used specialised ingredients, such as for instance xylitol, and groups of ingredients such as the categories of dietary fibre and probiotics. Furthermore, the distinction between naturally occurring and added functional food ingredients might influence consumers' acceptance of the considered food product, which could also have an effect on consumers' ingredient awareness. This applies also to the phrasing of ingredients – if the name of an ingredient sounds more chemical or natural.

*Table 5-6: Characteristics of functional food ingredients*

| Ingredient awareness | Research history | Market diffusion | Application breadth | Examples in the present study |
|---|---|---|---|---|
| **High** | Long | High | Broad | vitamin C, iodine, calcium |
| **Middle** | Middle | Middle | Broad to specialized | dietary fibre, omega-3-fatty acids, probiotics, antioxidants, phytosterols |
| **Low** | Short | Low | Specialised | glucosamine, xylitol |

Considering the three derived categories of ingredients, consumers' ingredient awareness seems to increase with the duration of scientific evidence: the longer the scientific history of a certain functional food ingredient the more familiar is this ingredient to a wide range of consumers. This phenomenon is also reported by Krutulyte et al. (2011). The application breadth reaches from very broad – vitamin C as a generalist well known for many indications – to specialised, for example xylitol for dental health. The high amount of application areas in case of vitamins and minerals might be due to the long research history.

Whereas the previous research mostly concentrates on one ingredient or product category, this study contributes to the existing body of consumer research literature by giving an overview of consumers' awareness of the ten different ingredients. This may help scientists and practitioners alike to differentiate between functional food ingredients or categories of these ingredients. Furthermore, most studies concentrate on one single determinant. By deriving the structural model this study gives an overview of the relationship between the different determinants and how they work together. In addition, this study contributes to the convergence literature showing an approach to include the consumer perspective into the analysis of convergence processes. As the consumer perspective in the convergence area is dependent on the product category, the present study addresses the consumer perspective in the converging area of functional foods, which has not been scrutinised before. In doing so, the functional ingredients represent the value-adding component in functional foods, and thus the ingredient awareness is addressed. The categorisation scheme in particular (ref. Table 5-6) delivers an approach of positioning strategies in the highly changing environment of converging industries.

One limitation of the study is that due to restricted resources only German consumers are included in the sample. However, there might be differences between consumers of distinct countries. Within further studies, a country comparison could be considered. Furthermore, this study only included ten different ingredients in the analyses. Further studies may concentrate on further functional food ingredients to give a more comprehensive view on the new industry segment of functional foods emerging at the borderline of the food and pharmaceutical industries. Although there are several studies, which show a relationship between awareness and dietary food choices, the question remains open whether and how consumers' ingredient awareness influences the dietary behaviour.

The practical implications are presented in the following paragraph. Firstly, it is very important for companies to know whether the consumer is aware of a certain functional food ingredient in order to define the right communication strategy. Therefore, this study aims to shed some light in the distinct ingredient awareness levels and their determinants. Secondly, the high influence of health motivation on ingredient awareness may be considered in terms of prevention through healthy food choices. However, as consumer awareness in close relation to consumer acceptance is a complex matter, more research is needed to scrutinise the different determinants on consumer awareness leading to consumer acceptance.

**Concluding remarks**

Consumers' ingredient awareness was very heterogeneous considering the ten scrutinised ingredients as some ingredients are well known among the interviewed German consumers and others are unknown. For preventive aspects, it is important that health motivation was the chief predictor of ingredient awareness. As health motivation showed the most important impact on consumers' ingredient awareness, prevention through *'healthy food choices'* might be possible. Consumers' information strategies influenced ingredient awareness while also being connected to consumers' health motivation. Therefore, these two predictors (health motivation in connection with information strategies for nutritional purposes) should be considered by elaborating consumers' ingredient awareness in order to derive a communication strategy at the intersection of the food and pharmaceutical industries.

The derived predictors from general nutritional knowledge show the same tendencies for the case of ingredient awareness. Therefore, ingredient awareness might be an overall important antecedent for the general nutritional knowledge of German consumers.

# 6 Discussion and conclusions

**Chapter 6 answers the overall research questions:**

***Main research question:***
*How can different convergence assessment perspectives be integrated to derive an overall framework with which to analyse convergence processes at the intersection of the food and pharmaceutical industries?*

***Research question focusing on the academic context:***
*How can the different convergence assessment perspectives and their combination contribute to the extension of existing convergence assessment approaches?*

***Research question focusing on the applied context:***
*How can the different perspectives be integrated into the innovation management process?*

Based on the previous chapters, which contributed to distinct theoretical perspectives, in the present chapter specific contributions will be pointed out regarding the overall theoretical framework with which to assess convergence processes, focusing on the research questions of the respective chapters (6.1). Next to the contribution per theoretical perspective, this chapter will discuss the overall theoretical contribution of this thesis regarding the innovation processes in converging industries. It will focus on the overall research questions with regard to the integration of the different perspectives (6.2). Practical implications in general as well as for the specific case of the functional food sector will be given in Section 6.3, before concluding with the limitations of the study and possible directions for future research (6.4).

## 6.1 Contribution per theoretical perspective

The present thesis discusses the assessment of the convergence process in functional foods using different theoretical perspectives. The life cycle perspective is used to derive an overview of the first three steps of science, technology and market convergence. The innovation value chain perspective describes different strategic types based on a comprehensive framework of convergence indicators. Cross-industry collaborations and their impact on convergence are scrutinised using a longitudinal case study approach analysing the emerging inter-industry segment between food and pharmaceutical companies. Besides the company-based perspective on innovation processes in converging industries, the consumer perspective is used to describe awareness of ingredients included in borderline products. These borderline products are launched by companies that are active in the emerging inter-industry segment of functional foods.

### 6.1.1 Converging industries from a life cycle perspective (Chapter 2)

Recent literature focuses on the evaluation of the front end of the convergence process (science and technology convergence) and uses bibliometric data including scientific publications and patents (Curran et al., 2010, Preschitschek, 2014, Golembiewski et al., 2015). These approaches are mainly used to anticipate converging areas. However, many convergence areas that have been described in the last years have already reached their maturity phase: for instance, the ICT sector was already described in the 1990's (Henderson and Clark, 1990, Katz, 1996, Prahalad, 1998). Consequently, assessment tools to analyse the changing market environment in the later phases of the convergence process increase in their importance for researchers and practitioners alike. While the specific concept of the patent life cycle (Ernst, 1998) is used to analyse science and technology convergence (Curran, 2010, Preschitschek, 2014), a general life cycle approach that also covers the later stages of convergence has not yet been used. The following two proposed research questions target this research gap.

***Research question 1.1 (Chapter 2):***
*To what extent can cross-industry activities be depicted in life cycles?*

***Research question 1.2 (Chapter 2):***
*What kinds of life cycle patterns can be identified in the convergence process?*

Employing a life cycle perspective delivers an approach that can cover the three steps of science, technology and market convergence, extending the previous methods to the consecutive step of market convergence. Although literature assumes that market convergence could hardly be measureable by large-scale monitoring concepts (Curran, 2010), the study in Chapter 2 using reported product launches contributes to the field by delivering a first quantitative approach to assessing market convergence. As the introduction of borderline products in the emerging inter-industry segment is considered, this thesis enhances the previous qualitative measures on market convergence (Preschitschek, 2014, Sick et al., 2015) while delivering a method at the product level. Next to the focus on the assessment framework of convergence, the study also contributes to a better understanding of convergence processes that have already reached the maturity phase.

The study in Chapter 2 concludes that the involved industry sectors cope differently with the upcoming challenges during the convergence process. Previous literature shows that the intensity of the activity in the emerging area differs between the involved sectors (see for instance Curran, 2010, Preschitschek, 2014, Bröring and Cloutier, 2008, Kim et al., 2015). Regarding the functional food market, the study in Chapter 2 shows a clear dominance of the food sector in probiotics which might be due to the proximity of the food sector to the main market outlet of functional foods. Thus, the dominance of an industry sector in an emerging field may be based on the proximity of this sector to the arising borderline products.

There is a time shift between the life cycles, which show the same activities of companies of distinct industry sectors at different times. These time lags between the life cycles support previous studies indicating a time lag between science and technology convergence (e.g. Curran and Leker, 2010). The clockspeed concept (Fine, 1998) can be adapted to analyse convergence from a life cycle perspective: the clockspeed of convergence can be measured by length of the time lags between the science, technology and market life cycles. In the case of probiotics, the clockspeed of the food sector is higher than that of the pharmaceutical sector, supporting the dominance of the food sector. Hence, the convergence clockspeed of an industry sector might indicate the dominance of that sector in the emerging field.

Previous studies use bibliometric datasets to anticipate industrial trends (Watts and Porter, 1997) and converging industries (Curran et al., 2010). The inception of the science life cycle shows the first phase in the convergence process, followed by the technology life cycle, which indicates the consecutive second phase. In the case of anticipating converging trends, convergence has to be detected in the first phases of science and technology convergence (Curran, 2010). Nevertheless, there are also convergence areas of great market relevance that have already reached a maturity phase showing market and industry convergence (for instance ICT, ref. Henderson and Clark, 1990, Katz, 1996, Prahalad, 1998). Thus, the simultaneous consideration of the science, technology and market life cycles delivers a research framework with which to identify the progress of the convergence process and therefore the relevance of the emerging field.

### 6.1.2 Converging industries from an innovation value chain perspective (Chapter 3)

While the study in Chapter 2 delivers an approach showing complete industrial developments by using a quantitative research strategy, the study in Chapter 3 complements this quantitative data by analysing active companies and deriving their strategic types using qualitative data. Since most studies on convergence concentrate on the industry-wide perspective (Curran, 2010, Preschitschek, 2014, Kim et al., 2015, Golembiewski et al., 2015), Chapter 3 enhances convergence literature by using a company perspective and by addressing the following research question.

***Research question 2 (Chapter 3):***
*How can convergence be assessed using an innovation value chain perspective?*

The approach in Chapter 3 is based on a set of indicators that have not been used for a comprehensive analysis before. Concurrently, the company's strategic types can be identified based on the comprehensive set of indicators, thereby delivering an assessment framework for the competitive environment of converging industries.

Cross-industry relationships occur along the innovation value chains of the four probiotic strains, and clear signs of science and technology convergence are found. The identification of science and technology convergence on the level of industry sectors can also be shown on a company level in this part of the study (Chapter 3). The comprehensive set of indicators delivers an extensive analysis framework of convergence processes on a company level, and can be used to derive a landscape description of the reconfiguration of innovation value chains.

Based on the in-depth description of the companies' activities in the convergence indicators, strategic types according to the framework introduced by Bröring and Cloutier can be identified (Bröring and Cloutier, 2008). Contrary to the literature describing the food sector as weak in technology (Sporleder et al., 2008, Grunert et al., 1997), the food companies active in probiotics follow the strategy of technology-intense product developers: they show increasing activities in the convergence indicators while having various cross-industry activities along the innovation value chain. Recent literature shows initial signs that only a small number of food companies leave the traditional path of low-cost and low-tech innovation (Vyas, 2014), while in general the food sector mostly relies on incremental innovation (e.g. Avermaete et al., 2004, Costa and Jongen, 2006). In contrast to the general food sector, the food companies active in the probiotics innovation value chains follow a *'technology-intense product developer'* strategy, delivering innovations in the form of borderline products. Thus, the approach of the comprehensive set of indicators identifies the strategies of the companies active along the innovation value chain in converging industries.

During convergence processes, the value chains of the involved sectors merge (Bröring and Cloutier, 2008). Since the reconfiguration of value chains can be a result of the competitive dynamics of convergence processes (Wirtz, 2001, Bröring and Cloutier, 2008), the analysis of the restructured innovation value chain and the therein included cross-industry activities delivers the basis for the description of the competitive environment in the emerging inter-industry segment. Competitor analyses provide the opportunity to understand and predict rivalry or market behaviour (see for instance Porter, 2008, Chen, 1996). These analyses are of increasing importance in converging industries as the number of possible competitors increases based on the involvement of different industry sectors. In other words, in converging industries companies stemming from different industrial backgrounds become competitors in the emerging inter-industry field. As a result, the analysis of the innovation value chain that is restructured in convergence enhances the convergence literature while delivering an approach with which to scrutinise the competitive environment in converging industries.

### 6.1.3 Converging industries from a collaboration perspective (Chapter 4)

While Chapters 2 and 3 deliver a comprehensive perspective on the convergence process, the study in Chapter 4 concentrates on the steps of market and industry convergence and scrutinises cross-industry collaborations in-depth. Especially in the emerging area of functional foods, the analysis of market and industry convergence is neglected in previous studies. The study presented in Chapter 4 addresses the following research question.

***Research question 3 (Chapter 4):***
*What kinds of cross-industry collaborations can be used to close competence gaps?*

By using a longitudinal case study approach, the study in Chapter 4 enhances convergence literature contrasting the cross-industry collaborations of the food and pharmaceutical sectors. It delivers an assessment approach based on two determinants (motivation and industrial scope of collaboration), which have not been used to scrutinise convergence processes before. As more innovative firms show increasing rates of collaborations (Eisenhardt and Schoonhoven, 1996), the number of cross-industry collaborations may in turn allow a conclusion to be drawn about the innovativeness of firms. Consequently, the analysis of cross-industry collaborations in convergence enables to identify the innovativeness of companies and thus on a higher abstraction level, the innovativeness of the involved industry sectors.

As the horizontal innovation across industrial boundaries is still a challenge to manage (Hahn, 2015, Gassmann et al., 2010), this thesis aims to enhance the literature focusing on innovation across industrial borders by considering the cross-industry collaborations in convergence. The considered companies from the food sector show more cross-industry collaborations towards the pharmaceutical sector compared to the cross-industry collaborations of the pharmaceutical companies towards the food sector. Thus, the selected food companies show a convergence-driving behaviour. As a result, the convergence-driving companies can be identified using the analysis of cross-industry collaborations, while the definition of the driving sector can be based on the life cycle approach (Chapter 2).

Various studies already use the distinction between a complementary and a substitutive convergence process (Greenstein and Khanna, 1997, Dowling et al., 1998). The convergence process of functional foods emerging at the interface of the food and pharmaceutical industries is already defined to be complementary (Bröring and Cloutier, 2008), which can also be shown with the present data by analysing the cross-industry collaborations as well as the product portfolios. These show that new markets, such as for instance the medical nutrition market, emerge alongside the remaining traditional food products and therapeutics. Next to the analysis of already existing product portfolios, planned products of newly established collaborations allow an early identification of future market developments. As a result, future market fields and their dimensions, such as being complementary or substitutive, can be identified based on the planned product portfolios of newly established cross-industry collaborations.

During the innovation process, companies try to gain and sustain a competitive advantage (Porter, 2007). Since this competitive advantage is based on a company's resources and competences (Barney, 1991), in convergence processes the heterogeneous resources and competences of the companies stemming from different industry sectors (Penrose, 1959) are used to develop new products for the emerging inter-industry segment. While in the first phases of the convergence process resources and competences are built based on cross-industrial activities in joint research and development (measured by scientific publications and patents, ref. life cycle approach of Chapter 2), in the later stages of convergence the resources and competences are gathered by the internalisation of external knowledge (Gambardella and Torrisi, 1998), for instance through acquisitions (Bower, 2001). By using a longitudinal case study approach, the structural formation of convergence can be assessed based on the timely development of cross-industry collaborations, thereby delivering an assessment approach for the progress of convergence on a company level.

### 6.1.4 Converging industries from a consumer perspective (Chapter 5)

While the preceding studies in this thesis focus on the company perspective of convergence processes, Chapter 5 contributes to the convergence literature by delivering an approach with which to include the consumer perspective in the innovation process of converging industries. Knowledge about a certain ingredient is the precondition for the knowledge about the health effect of this ingredient (Wansink et al., 2005), and thus for consumer acceptance of the functional food (Pounis et al., 2011, Jones and Jew, 2007). Although previous studies show a great research interest in consumer acceptance of functional foods (see for instance Krystallis et al., 2008, Cox et al., 2011, Van Trijp and Van der Lans, 2007), literature about consumers' awareness of the inherent health ingredients is scarce. As ingredient awareness is a precondition of acceptance and therefore the innovation success of borderline products, the analysis of ingredient awareness among consumers targets the following research question.

***Research question 4 (Chapter 5):***
*How can convergence be assessed using a consumer perspective?*

The study in Chapter 5 addresses the research gap by analysing consumers' awareness of ten health ingredients as well as the determinants of that awareness. This thesis delivers an approach that includes the consumer perspective into the innovation process of the converging industries at the interface of the food and pharmaceutical industries. Although there are first attempts to include consumer perception into the innovation process in converging industries (Lee and Cho, 2015, Won et al., 2012), current studies on the consumer perspective focus on the ICT sector, and thus on a technology-driven convergence area. This thesis enhances convergence literature by using the example of functional foods, which is a demand-driven convergence area.

Results of the study in Chapter 5 indicate that the central predictor of ingredient awareness is health motivation, which shows the relationship between functional food ingredients and their health benefits beyond their nutritional value. Because the ingredient-indication relationship has to be learned, for instance through education (Parmenter et al., 2000), companies active in the functional food sector may profit from investing in consumer education about their products and possible health effects. The two main active sectors – foods and pharmaceutics – differ in their communication channels towards consumers, which in turn results in different ways in which consumers obtain their information. While pharmaceutical marketing mainly addresses health care professionals (Levy, 1994, Stros and Lee, 2014), food marketing focuses on consumers (Costa and Jongen, 2006). Consequently, for functional food marketing, the pharmaceutical sector lacks the expertise in consumer marketing regarding the communication towards consumers. As a result, the knowledge about the determinants of consumers' ingredient awareness enables researchers and practitioners alike to find the right communication strategy during the innovation process to improve consumers' understanding of possible health effects of functional ingredients. In addition, the determinants of ingredient awareness define the target group for functional foods.

Since the predictors of ingredient awareness show the same tendencies as the predictors of overall nutritional knowledge, ingredient awareness may be an overall important antecedent for general nutritional knowledge. This relationship towards the traditional food sector implies that consumers perceive functional foods to be closely related to the food sector. In contrast, the main predictor of ingredient awareness is health motivation. Because this central determinant shows a clear relation to the pharmaceutical sector delivering health products, the intertwined relationship of the food and pharmaceutical sectors in consumers' perception about functional foods and their ingredients is evident. Thus, the predictors of consumers' awareness about convergence products can be used to analyse consumers' perception of the involvement of different industry sectors.

Convergence products fulfil a need that is not yet perceived by consumers since through merging the characteristics of the traditional products, new product values emerge (Bröring, 2005). Consequently, due to the highly differing characteristics of convergence products, for each convergence field the underlying setting of relevant characteristics must be identified, such as for instance ingredient awareness in the inter-industry segment of functional foods. After identification, consumers' awareness about this special case may be used to form a categorisation scheme, which could in turn be used in decision-making in the innovation process of converging industries.

## 6.2 Overall theoretical contribution

Driven by the novelty and complexity of converging industries, multifaceted studies focus on different areas of convergence. The main aim of this thesis is to contribute to the existing literature on convergence by delivering different perspectives with which to assess the convergence process. In this section of the thesis, a synthesis of the conclusions of the studies in Chapters 2-5 is delivered, focusing on an overall research framework with which to assess convergence while integrating the different perspectives (6.2.1). The chapter then elucidates the academic conclusions (6.2.2) and methodological contributions (6.2.3) of the thesis.

### 6.2.1 Main conclusions

Converging industries imply highly changing competitive environments. Therefore, the evaluation of this phenomenon is of high importance for researchers and practitioners alike. While a standard competitive environment is limited to one industry sector, in converging industries companies from different industry sectors become competitors. Therefore, convergence evaluation measures have to regard various specifics of the different involved industry sectors, which may be contrary to each other. This is addressed by the main research question of this thesis.

***Main research question:***
*How can different convergence assessment perspectives be integrated to derive an overall framework with which to analyse convergence processes at the intersection of the food and pharmaceutical industries?*

Based on the different perspectives used to assess convergence processes, this thesis reveals that at the intersection of the food and pharmaceutical industries, first a rapidly changing market environment is evident while second, different competence areas of the involved industrial areas come into conflict. Against this backdrop, two main implications for an overall assessment framework of convergence industries arise: first, **convergence evaluation** with regard to the on-going convergence process reflecting the changing market environment; and second, the analysis of the emerging competitive environment with regard to the **converging competences.**

While former models focus on the anticipation of convergence processes by analysing sole patent data (e.g. Curran and Leker, 2011, Curran et al., 2010), these models could be enhanced to a **convergence evaluation model**, which reflects the complete process using different measures for the consecutive phases. As many convergence areas have already reached the maturity phase, different perspectives used to analyse the complete process become relevant. Based on the presented assessment perspectives, a two-step approach for a convergence evaluation model can be derived. The first step should consider a quantitative measure, such as the presented life cycle approach, to define the phase of the process. Based on the phase determination, the appropriate measure for an in-depth analysis of the respective phase can follow. If an early phase is detected, bibliometric data such as scientific publications and patent documents should be analysed in-depth, for example with regard to the specific subject areas of the publications or patents, to determine the future developments. If a later phase is identified, in-depth analysis of the already emerging competitive environment can be applied, such as consumer studies, to evaluate the maturity of the market. Thus, evaluation models should include the life cycle approach in combination with an in-depth analysis of the detected phase.

This proposed convergence evaluation model is adaptable to other convergence areas, as the general measures in the life cycle approach (scientific publications, patents, product launches) can be applied in the same way to different industry sectors. The consecutive second step is dependent on the convergence area and has to be aligned accordingly. For example, the consumer perspective in particular can deliver insights about the relevance of a mature convergence market as the consumer acceptance of the borderline products determine the market success.

External factors such as changing regulations affect the convergence process. The health claim regulation in Europe reflects the convergence in regulation at the intersection of the food and pharmaceutical industries (Hermann, 2009, Herath et al., 2008). Regarding the chronological development of convergence events, regulation mainly reacts to new borderline products and therefore occurs after market convergence, where new product-market combinations arise. As regulation is discussed as a trigger for and concurrently as a barrier to innovation (Katz, 1996, Rennings and Rammer, 2011), the positive or negative impact of the regulation on innovation can be identified in the life cycle of product launches. Thus, external factors can be integrated into the convergence evaluation model. Furthermore, this thesis delivers a first approach to measure the application of the converged legislation while analysing the activity in health claim submissions. Since the converged regulation is as specific as the products of the convergence area, measures for regulatory convergence have to be aligned to each specific case.

Because the **convergence evaluation model** covers the complete process, the industry-wide analysis of convergence processes can be implemented in distinct industrial areas at different stages. Based on this model, comparative analyses and trend analyses of complete sectors become possible. In addition, external determinants and their impact on the convergence process can be scrutinised.

While the convergence evaluation model considers industry-wide developments, the competitive environment should be considered on a company level showing the **converging competences**, which entail different levels of complementarity. With regard to the different competences of the involved sectors, assessment approaches that focus on high-tech industries concentrate on technology-driven measures such as patents (e.g. Lee et al., 2009, Altuntas et al., 2015). In contrast, the analysis of market sectors focuses on consumer interests (e.g. Kotler et al., 2012). The functional food area shows an emerging field in which the consumer-oriented food sector and the research-intensive pharmaceutical sector become competitors. For this reason, this thesis provides measures from a high-tech perspective (e.g. patents) and a consumer perspective (e.g. product portfolios).

Since the results indicate that the traditionally consumer-oriented food sector is highly active in basic and applied research (so in scientific publications and patents), a movement towards the research-intensive pharmaceutical sector is obvious. Conversely, the companies of the pharmaceutical sector acquire expertise in consumer marketing. In converging industries, not only do the involved industry sectors collaborate to develop and launch borderline products, but the characteristics of the sectors also start to become more alike. Consequently, convergence assessment approaches have to consider the different core competences of the involved sectors.

One challenge regarding the innovation in the converging area of functional foods is the expertise needed in clinical trials to substantiate a potential health effect of functional ingredients (Jones and Jew, 2007, Arai et al., 2001). Traditionally, the expertise in clinical trials is rooted in the pharmaceutical industry. However, the food sector is trying to close this competence gap, as is shown by its extensive activity in basic research measured by scientific publications and patents focusing on functional ingredients. Another challenge of functional food innovation is the integration of the functional ingredients into the product matrix (Benner et al., 2003, Krutulyte et al., 2011). While the integration of functional ingredients into functional foods, and therefore the integration into a traditional food product, belongs to standard processes in the food industry, the application of functional ingredients in dietary supplements that have a drug-like appearance is closely related to the expertise of pharmaceutical companies. Although the food industry might lack research strength in clinical trials and the development of drug-like products, this thesis shows an impetus of the food sector towards the inter-industry segment of functional foods: the food sector strives to develop product categories distant from its traditional area, such as dietary supplements. This might explain the sector's higher level of activity in basic research as a way to develop competences in clinical trials and in the development of drug-like products. On the other hand, the pharmaceutical sector stays closer to its traditional products as it concentrates on dietary supplements. Although an interdependency can be shown between the market outlet of the borderline products and the traditional products of one sector, convergence-driving companies also strive towards products with a great distance from their traditional field. As a result, convergence assessment approaches have to consider the differences in competence complementarity between the involved sectors, as well as between the launching company and the borderline product.

Market convergence delivers the unifying element between the previously technology-driven perspective of companies and the product perspective that is driven by the demand of consumers (ref. to the concepts introduced by Pennings and Puranam, 2001, Bröring, 2005). Whereas traditionally the pharmaceutical sector relies on technology-driven innovation processes (Howells et al., 2008), the food sector concentrates on demand structures (Bröring, 2005). The special case of the emerging functional food market is related to the general consumer trend of health and well-being (Menrad, 2003, Roberfroid, 2000b, Bigliardi and Galati, 2013), and thus delivers a demand-driven convergence process in contrast to other convergence areas such as ICT, which show a technology-driven convergence. This might explain the dominance of the food sector in all phases of the convergence process as a result of its general consumer orientation.

Since an overall assessment approach to analysing **converging competences** should include first the consideration of the different core competences and second the complementarity of competences, a combination of the following perspectives seems to be useful. While the analysis of cross-industry activities in scientific publications, patents and product launches (life cycle approach) delivers the basis from which to identify the different core competences, the in-depth analysis of cross-industry collaborations (competence convergence approach in innovation value chain and collaboration perspective) indicates the level of competence complementarity. Based on the approach used to analyse converging competences, the underlying dynamics of convergence processes can be analysed, thus identifying the specific convergence behaviour of different sectors and companies. Although the competences are industry-specific, the presented measures can be adapted to other convergence areas analysing, first general cross-industry activities, and second the different collaboration types.

One driver of joining cross-industry collaborations is to close competence gaps. The study in Chapter 3 discusses different collaborations using the concept of *'competence convergence',* whereas the case study on the emerging inter-industry segment frames different collaboration forms in the procedural perspective of market and industry convergence (for recent discussions about measurement approaches of market convergence ref. to Preschitschek, 2014, Sick et al., 2015). Competence gaps may emerge in all stages during the convergence process, which is shown for instance in Chapter 3 focusing on the innovation value chain approach. Cross-industry activities occurred in all convergence indicators, for instance science and technology convergence. Thus, the elaboration of cross-industry collaborations should be based on a broader concept than simply focusing on market convergence. For instance, competence gaps can already arise during basic research (science convergence) and can as a result be closed by joint research in cross-industry collaborations. However, this thesis shows a time lag between the occurrence of the different convergence phases and the occurrence of cross-industry activities within these phases. Although competence gaps may arise and be closed during all phases of the convergence process, cross-industry collaborations may occur with a delay.

As a consequence, the convergence evaluation model and the converging competences are linked to each other; this is because the converging competences can be detected at different stages in the progress of the convergence process. In other words, the different perspectives serving to describe the different levels of convergence are not detached from each other. For instance, technology and market convergence are linked to each other since technology can be developed in-house or acquired externally (Duysters and Hagedoorn, 1998) – therefore mergers and acquisitions are linked to both the concept of technology and market convergence since companies acquire other companies to close competence gaps on the technological level.

In summary, this thesis enhances the research field of convergence by delivering an overall assessment framework with which to scrutinise the convergence process, focusing first on the convergence evaluation and second on the converging competences (ref. Figure 6-1). This contributes to the general conceptualisation of convergence processes, which can be adapted to other recent convergence areas and allows comparative analyses of different convergence areas.

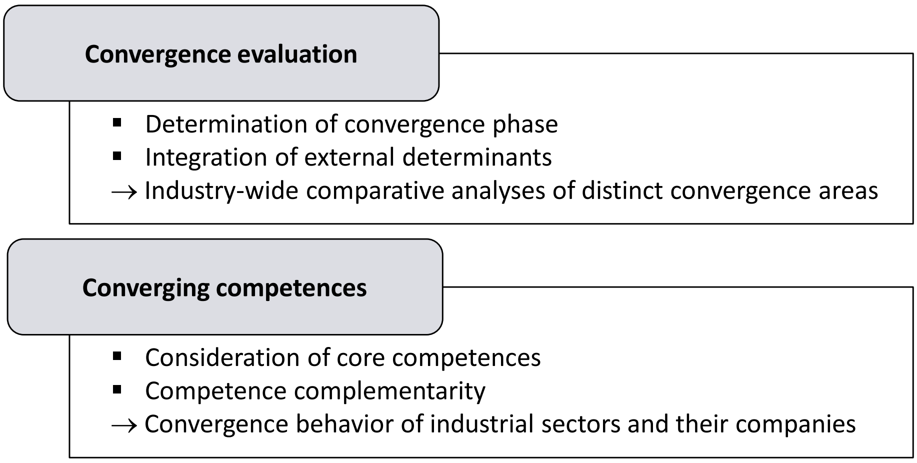



*Figure 6-1: Main contributions with regard to the main research question*

### 6.2.2 Academic conclusions

Although recent studies consider different convergence phases (e.g. Curran and Leker, 2010), they mainly cover the front end, including science and technology convergence. The following section addresses the research question with regard to the academic context in order to integrate the different assessment perspectives with the goal of extending the already existing approaches:

***Research question focusing on the academic context:***
*How can the different convergence assessment perspectives and their combination contribute to the extension of existing convergence assessment approaches?*

This thesis enhances the convergence literature by using a mixed-method approach to scrutinise the complete convergence process. It especially includes the later phases of market convergence in the procedural analysis (Chapters 2 and 3), and delivers approaches to scrutinise the neglected area of market and industry convergence in-depth (Chapters 4 and 5). Thus, the **scope of analysis** regarding the convergence process is extended. The increasing importance of the analysis of later convergence phases is due to the various convergence areas already reaching a maturity phase (for instance the ICT sector, ref. Henderson and Clark, 1990, Katz, 1996, Prahalad, 1998).

Recent studies on the analysis of market convergence concentrate on scrutinising cross-industry collaborations and depict the supply side (Sick et al., 2015, Preschitschek, 2014), while the demand side is neglected. This study enhances the theoretical perspective of market convergence while analysing the demand side of market convergence, following first a quantitative approach using the product launches in the life cycle perspective, second a qualitative approach using the product portfolios in the cross-industry collaborations, and third the consideration of the consumer perspective. Thus, by using the demand side of market convergence, the scope of convergence analyses is extended. This enables researchers and practitioners alike to analyse later phases of convergence processes from the supply and demand sides.

As the convergence phenomenon focuses on industrial changes, most studies concentrate on an industry-wide perspective (e.g. Kim et al., 2015, Curran et al., 2010). Nevertheless, industrial changes are based on the specific business activities of the involved companies. This thesis contributes to the existing literature by delivering assessment approaches on an industry-wide and on a company level, thereby also using the company level as **unit of analysis**. Consequently, the concurrent analysis of the industry and company perspectives makes it possible to identify interdependencies. While the industry-wide perspective focuses on industrial changes, the company perspective can deliver the underlying motives of the industry sectors, such as for instance the motivation to join a cross-industry collaboration or the strategic types along the innovation value chain.

Most studies that focus on analysing patent data in terms of convergence use the SIC code of each involved company to determine the industrial background. In doing so, the underlying determination of industry sectors is on a company level whereas the analysis of the company perspective as such and the different cross-industry relationships are neglected. Patent data can be used to analyse convergence processes from the industry (life cycle approach) and company perspectives (innovation value chain approach). Thus, the industry-wide usage delivers a superordinate evaluation perspective, while the usage on a company level reveals the interwoven relationships between companies of distinct industry sectors along the innovation value chain. Nevertheless, the dominance of the food sector could be shown on a company and on an industrial level.

Besides the company level, this thesis uses the consumers perspective with regard to the product characteristics, thus to functional ingredients, to extend assessment approaches of the innovation process in converging industries. Because consumers' acceptance of borderline products is dependent on the specific convergence context, the determinants, which influence consumers' awareness and thus acceptance, vary case by case. Consequently, only the methodological approach can be transferred to other convergence areas. Three steps have to be considered: first, the identification of the value-adding product characteristics; second, the evaluation of consumers' awareness and its determinants; and third, the derivation of a categorisation scheme for positioning strategy. Thus, the research setting of the present consumer study delivers a guideline with which future convergence areas can be analysed in order to develop a structural categorisation of the borderline products and their estimated consumer acceptance.

Although the literature already described the convergence phenomenon several years ago (Henderson and Clark, 1990, Katz, 1996, Prahalad, 1998), assessment approaches are still in the on-going scientific discussion (Curran, 2010, Sick et al., 2015). This thesis enhances the literature on convergence by its **adaption of theoretical concepts**. By analysing convergence from a life cycle perspective, the concept of industry clockspeed is adapted to *convergence clockspeed*, measured by the length of the time lags between science, technology and market life cycles. The basic concept of organisational learning showing *exploration and exploitation* is adapted to the context of convergence by analysing the motivation behind cross-industry collaborations leading to a categorisation scheme of different collaboration types. While many studies focus on the general nutritional knowledge of consumers, this thesis adapts the determinants to the special case of *ingredient awareness*.

In summary, this thesis enhances the research field of convergence by delivering an overall assessment framework with which to scrutinise the convergence process based on the extension of the scope and the unit of analysis next to the adaption of theoretical concepts (ref. Figure 6-2). This contributes to the general conceptualisation of convergence processes, which can be adapted to other recent convergence areas. In addition, the special attention given to the later steps in convergence takes into account that many convergence areas have already reached the maturity phase.

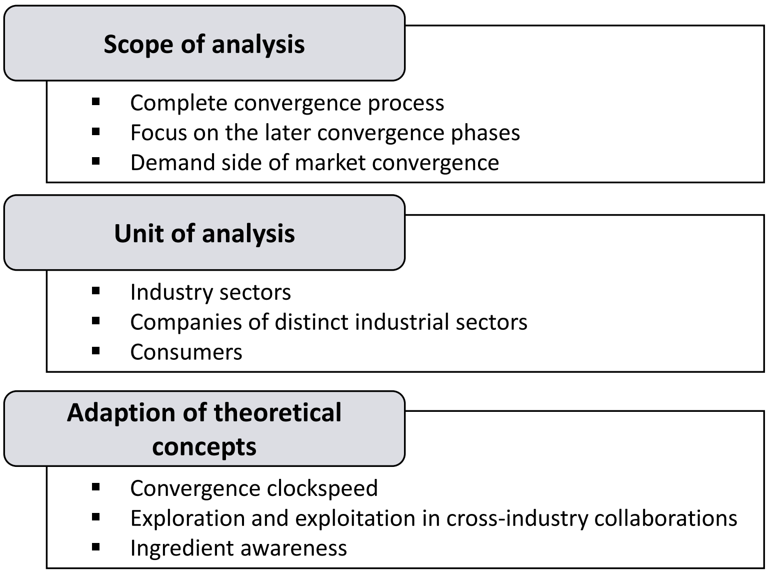



*Figure 6-2: Overview of academic contributions*

### 6.2.3 Methodological contributions

This thesis provides multiple contributions from a methodological point of view. While the overall aim of the thesis is to deliver an assessment framework for convergence processes, the diversified selection of distinct methodological approaches considers the multifaceted challenges involved during the complete convergence process and during its different phases. The consideration of one sole method is not sufficient to cover the complete process with its peculiarities within the different phases.

Within the innovation process, there are not only success factors connected but also risks. These can be divided into two categories: the ideas that are undeservedly screened out or overlooked, and the unnecessary invested development resources for product failures (Van Kleef, Van Trijp et al. 2002). This overview of measures delivers one approach to meet these risks in converging industries. On the one hand, the comprehensive evaluation model for the complete convergence process can be used to identify relevant convergence areas, and thus the identification of promising ideas, which might possibly have been screened out due to their distance to the previous product portfolio. On the other hand, the inclusion of the consumer perspective in the early development stages delivers the possibility to define the right target group as well as the communication strategy in order to avoid the unnecessary investment in development resources.

While most studies apply to the overall convergence phenomenon, convergence is often equated to technology convergence (Borés et al., 2003, Nyström, 2008) since the general idea of convergence goes back to the overlapping of technologies (Rosenberg, 1976, Stieglitz, 2002). Concurrently to the focus on technology convergence, patents are used as the main measure for convergence (e.g. Preschitschek et al., 2013, Kim et al., 2015, Kim and Kim, 2012). However, like the overall convergence phenomenon, the measures should not be reduced to the technological level, and thus to patents. Although patents present a valuable information resource, for instance about the reflection of variations in research productivity (Danguy et al., 2014), patent data lacks information about the commercialisation of the described technology, so the market relevance. On the one hand, market relevance can appear in product launches. The study delivers two approaches to reflect product launches: a quantitative measure of reported product launches that uses a life cycle perspective, and a qualitative measure of product portfolio descriptions that uses a collaboration perspective. On the other hand, market relevance can be measured inter alia by customer appeal (Barjolle and Sylvander, 2002). Therefore, the study at hand includes the consumer perspective in the consideration of the convergence process.

The health claim regulation as such shows convergence in regulation, for example by applying the same standards for different industry sectors. This thesis enhances the evaluation of convergence while delivering a first approach to assess regulatory convergence based on the activity of companies applying the regulation.

Besides the general methodological contributions, specific contributions for each methodological approach are derived in the context of the overall assessment framework in the following paragraphs.

The **large-scale monitoring concept** in Chapter 2, which uses a life cycle perspective, enables the superordinate analysis of the convergence process in functional foods. Bibliometric data allows for the analysis of the first three phases of science, technology and market convergence based on scientific publications, patents and reported product launches. As these data sets are publicly available, the process of information procurement is simplified. Although this part of the thesis mostly relies on descriptive data, the contribution of the large-scale monitoring concept arises around the longitudinal analysis of industrial developments. This longitudinal consideration delivers an analysis instrument with which to anticipate developments on the science, technological and market levels in order to identify timing strategies. In addition, the methodological contribution lies in the first application of a general life cycle approach in convergence.

The two qualitative data sets in Chapters 3 and 4 complement the superordinate analysis while explicating the peculiarities of the involved companies stemming from different industrial backgrounds. The application of a **mixed-method approach** in the study in Chapter 3 adds value to the assessment framework of convergence processes because the underlying strategic types on a company level can be assessed. This type of study design is appropriate for studying the interwoven relationships between the companies from different industrial backgrounds along the innovation value chain, because the set of indicators delivers facets that have not been considered in a structured analysis of convergence before.

In the study presented in Chapter 4, the **longitudinal case study approach** contributes to the qualitative assessment of convergence processes by analysing cross-industry collaborations. The four cases deepen the understanding of the collaboration strategies in the food and pharmaceutical sectors. The longitudinal analysis of the two sectors focusing on the same inter-industry segment delivers an in-depth understanding of the sectors' movement towards each other over time. The application of the two determinants (motivation and industrial scope of collaboration) enhances the literature on convergence by delivering a measure with which to analyse the structure of the later stages of convergence processes. In Chapters 3 and 4, the consideration of licensing agreements extends convergence literature about cross-industry collaborations, since licensing agreements have not yet been considered as a measure in these studies.

The understanding of the convergence process is deepened through the consumer study using **structural equation modelling** to scrutinise the determinants of ingredient awareness focusing on the later stages of market and industry convergence. This method provides the possibility to explore the interwoven relationships between the different determinants of ingredient awareness. Since ingredient awareness is a precursor for consumer acceptance, the insights into ingredient awareness and its determinants are pivotal for the success of products. The structural equation modelling is complemented by a structured categorisation of the different functional ingredients in order to derive a framework for communication strategy based on heterogeneous ingredient awareness.

## 6.3 Practical implications

The studies of this thesis aim to scrutinise the challenges faced during the innovation process in converging industries, and to derive an assessment framework of convergence processes. In general, actors from different industrial backgrounds can draw lessons from these studies (6.3.1). By using the example of functional foods, the findings can assist with decision-making in the food and pharmaceutical industries in particular (6.3.2). This section addresses the research question with regard to the applied context in order to integrate the different assessment perspectives into the innovation management process.

***Research question focusing on the applied context:***
*How can the different perspectives be integrated into the innovation management process?*

### 6.3.1 Practical implications for converging industries in general

While the theoretical contribution of this thesis lies in the assessment framework of convergence processes, the practical implications arise around the possibility of using these methodological approaches during the innovation process in converging industries. Depending on the phase during the innovation process, the structural categorisation of assessment methodologies delivers a set of measures that can be adapted to the routine innovation process in the company. In other words, measures for different steps in the innovation process are delivered that can be used in decision-making. Since the presented measures in Chapters 2-4 rely on publicly available data sets, companies can straightforwardly employ the assessment approaches. While the *convergence evaluation model* can serve for the **identification of relevant convergence areas** and **anticipation of convergence trends**, the inclusion of the analysis of *converging competences* enables companies to identify **strategies** to cope with the challenges of advanced convergence markets.

Based on the convergence evaluation model, **relevant** convergence markets can be identified. Next to the definition of the convergence progress, the knowledge about the emerging markets at an early development stage enables companies to **anticipate** future market trends (e.g. Curran et al., 2010). Furthermore, the identification of future market trends can be based on cross-industry collaborations, which allows companies to react more quickly and efficiently to the rapid market changes. The knowledge about the products that may be launched by direct competitors enables companies to differentiate their products from those of their competitors. Acquisitions deliver information about the future market fields by summarising the resources and competences of the involved partners to derive new borderline products. In addition, the detection of an industry's clockspeed in convergence processes enables companies to predict the speed of the future convergence developments. Thus, the companies neighbouring the inter-industry segment are able to prepare for the emerging market and to position themselves in order to gain a competitive advantage.

Dependent on the convergence maturity constituted by the occurrence of the science, technology or market life cycle, the market entry **strategy** of a company might be determined. Since the right timing is one major challenge within innovation management (e.g. Fischer and Himme, 2011), a timing strategy for the rapidly changing market environment in convergence could be based on the analysis of science, technology and market life cycles. By identifying an early phase of convergence, the process might be anticipated and the company's own activities in basic and applied research might be planned to try to make the company a pioneer in the market and gain first-mover advantages (Lieberman and Montgomery, 1988, Sporleder et al., 2008, Briggeman et al., 2006). In case of the identification of later convergence phases already showing borderline products in the market life cycle, options of a follower strategy could be considered (e.g. Chang et al., 2003, Hauser and Shugan, 2008).

The comprehensive set of indicators with which to analyse convergence on a company level supports companies in evaluating their own strategic position and the position of the competitors along the innovation value chain, and thus the competitive environment in the restructured innovation value chain. The indicator of regulatory convergence enables companies to identify the target market of their competitors in the future, as the competitors strive to communicate a certain health benefit to consumers. Based on this knowledge, one's own strategies to enter the market can be derived.

The identification of the appropriate cross-industry collaboration form in certain convergence environments enables companies to decide which collaboration form best fits the competitive environment and the overall company strategy. The right collaboration strategy based on the convergence phase can be taken by combining the superordinate perspective of the determination of the convergence progress with the analysis of cross-industry collaborations.

### 6.3.2 Practical implications for the emerging area of functional foods

While most of the derived assessment approaches contribute to convergence processes in general, some specialities for the functional food sector can be drawn referring to the presented challenges of the innovation process in functional foods (ref. Table 1-1). Especially by evaluating later phases of convergence processes, the assessment approaches of the consumer perspective are highly dependent on the borderline products and therefore on the convergence area.

Next to the general determination of the convergence phase of the inter-industry segment of functional foods, the presented *convergence evaluation model* enables companies of the food and pharmaceutical sectors to identify the convergence maturity of the different available functional ingredients within functional food products. There are differences in the maturity of the distinct functional ingredients: for example, some ingredients such as vitamins and minerals encompass a long research history and therefore a longer market availability than for instance probiotics or phytosterols. The discovery a new functional ingredient might even imply a new convergence process. Nevertheless, as the new functional ingredient would also focus on the inter-industry segment of functional foods, the comparative analysis possibilities of the convergence evaluation model in particular help to identify the relevance and future trends of possible new functional ingredients.

This study delivers on the one hand in-depth analysis of the specific ingredient category of probiotics, while on the other hand showing the variety of different functional ingredients in the collaboration and consumer perspectives. In doing so, even within the category of probiotics differences between the bacteria strains can be shown (Chapter 3, innovation value chain perspective). This demonstrated the heterogeneity of emerging inter-industry segments leading to the necessity of assessment frameworks to analyse the convergence process. Furthermore, the inter-industry segment between the food and pharmaceutical sectors does not only deliver functional foods and dietary supplements. Cosmeceuticals also arise as another borderline category. Interestingly, both types of borderline products rely on the same functional ingredients: for instance, probiotics can be found in functional foods as well as in skincare. Thus, strength in cross-industry activities that focus on the underlying functional ingredients delivers the opportunity to enter both emerging areas. For example, Nestlé shows great strengths in basic research across industrial borders and in cross-industry collaborations to focus on both the functional food and the cosmeceutical markets. Consequently, strengths in cross-industry behaviour increase the opportunities to enter neighbouring emerging inter-industry areas or even to create them.

The *competences* of the food and pharmaceutical sectors *converge*, for example, to substantiate a health benefit through clinical trials. The underlying knowledge is expressed in the scientific publications in the relevant field. As scientific publications are considered to be the first step in the life cycle approach, on the one hand the relevant convergence areas can be identified based on scientific publications. On the other hand, the information within the identified scientific articles becomes available and the relevant information about the health effect, for instance, can be used directly at the front end of the innovation process. The same applies for the consideration of patent documents. On the one hand, the relevant technological developments can be identified, while on the other hand the information inherent in patents can be used to analyse, for instance, the complexity of food compositions.

The analysis of cross-industry collaborations of the food and pharmaceutical sectors reveals a higher intensity of the food sector in cross-industry collaborations towards the emerging inter-industry segment of functional foods. While the food sector seems to try to internalise its missing research competences, for instance with joint ventures focusing on collaborative research, the pharmaceutical sector seems to overcome the competence gap of consumer marketing strategies by selling the respective ingredients to food companies strong in consumer marketing.

The studies in Chapters 2 and 3 focus on probiotics as a special ingredient in a successful market category (Annunziata and Vecchio, 2013, Saxelin et al., 2005). In the case of probiotics, both studies reveal that the food sector is dominant in driving convergence. Nevertheless, the development of functional foods increasingly needs the research strengths of the pharmaceutical sector; for example, in Europe the authorisation of health claims according to the health claim regulation (EC No 1924/2006) requires clinical trials to scientifically prove the health benefit beyond the nutritional value. The reason for a health claim rejection often refers to insufficient medical trials, so the conduction of clinical trials plays a pivotal role in successfully submitting a health claim. In turn, the health claim of the product increases consumers' acceptance of functional food products and thus success in the innovation process.

In addition, because stating a health benefit is not allowed for all ingredients for which a possible health effect is discussed, consumer awareness of the ingredient and its possible health benefit is crucial to the product success. As a result, the consumer study presented in this thesis is relevant for companies active in the functional food market in judging consumers' awareness of the functional ingredient and thus in applying the right communication strategy. Next to the successful innovation process based on the knowledge of consumers' ingredient awareness, consumers' understanding of the health benefit delivers opportunities for the prevention of chronic diseases through healthy food choices.

As consumer research in all stages of the innovation process fosters the later market success of the developed products (Van Kleef et al., 2005), special attention is paid in the present thesis to the consumer perspective. Especially for the innovation process of borderline products such as functional foods, consumer acceptance is crucial (Grunert et al., 2012, Carrillo et al., 2012) since, due to the increasing complexity of the products, consumers should understand the health benefits beyond the nutritional value. While in market-oriented industries such as the food sector consumers' acceptance studies are already integrated in the innovation process, research-intensive sectors such as the pharmaceutical sector could profit from a consideration of consumer aspects. While consumer marketing focuses on communicating directly to consumers (Roberfroid, 2000a), the distribution through health professionals from a pharmaceutical perspective delivers the opportunity to carry more complex messages (Lagace et al., 1991) as they could be explained by the health professionals to the consumers. In this way, the communication channel through health professionals makes it possible to transfer more complex ingredient-health indications. As a result, the same ingredient could be marketed in different product categories, depending on the launching sector. In addition, knowing the underlying consumers' ingredient awareness delivers an approach with which to decide how to implement this ingredient in the already existing product portfolio. Moreover, consumer awareness of the borderline products and the inherent characteristics enables companies to define the target group and therefore the appropriate communication strategy.

In summary, this thesis enhances the research field of convergence while delivering practical implications based on the overall assessment framework with which to scrutinise the convergence process (ref. Figure 6-3). This contributes to the general conceptualisation of convergence processes, by referring to the convergence evaluation model and the converging competences.

**Converging industries in general**

- Convergence evaluation model: identification of relevant converging areas, anticipation of trends
- Converging competences: identification of strategies

**Converging area of functional foods**

- Convergence evaluation model: identification of differences between functional ingredients
- Converging competences: bibliometric data to identify research basics

*Figure 6-3: Practical implications with regard to the main conclusions*

## 6.4 Limitations and directions for future research

In the following section, the limitations as well as the directions for future research will be discussed. While the main contribution of this thesis is an integrated perspective on the complete convergence process, this perspective might concurrently also be discussed as the main limitation. Based on a superordinate perspective, certain partial aspects cannot be analysed in-depth at the same time. Future research can complement this superordinate assessment framework with in-depth analyses of the different phases in convergence processes.

This thesis focuses mainly on publicly available data. Although publicly available data deliver advantages such as time-saving (Curran et al., 2010), the neglect the internal company perspective. Future studies could address this research gap by considering the internal perspective, for instance by using expert interviews to evaluate the cross-industry activities in-depth.

Since the creation of innovation clusters between the food industry, universities and authorities is one strategy to promote the innovation process (Mark-Herbert, 2004), future studies might focus on the involvement of research institutes in cross-industry collaborations.

Furthermore, as the evaluation of convergence from the industry-wide and company perspectives is not restricted to a certain region in the world, future studies might focus on the distinction between convergence processes in different regions.

The methodological limitation to the study in Chapter 2 is related to the lack of more recent data on the functional food sector. However, the application of the life cycle concept retains its importance since the example of the emerging sector of probiotics has already reached a later convergence phase, showing market convergence of the arisen borderline products in the area of probiotics. Future studies could use the assessment framework to analyse other advanced convergence areas.

The explorative focus on the comprehensive set of convergence indicators delivers an approach to be validated in future studies analysing other convergence areas. In doing so, these indicators can be extended to the peculiarities of the different convergence areas, such as the consideration of the respective legal framework. As the consideration of cross-industry activities along the innovation value chain delivers an in-depth description of the competitive environment, the method could be extended to others stemming from the traditional competitor analysis by considering the peculiarities in converging industries.

Using the product portfolio of both the involved companies and the emerging cross-industry collaborations delivers a first superficial analysis method. Future studies could contribute to the convergence assessment framework by deriving a structured analysis tool of product portfolios. In addition, the analysis of the product perspective could be enhanced by the use of other databases that already summarise the product launches of the respective industrial area based on store checks. Since the study in Chapter 4 relies on publicly available data on cross-industry collaborations, these data could be validated by expert interviews delivering the internal perspective on these activities.

The consumer study in Chapter 5 lacks transferability to other convergence areas sicne the concept of ingredient awareness is highly specialised for the functional food sector. However, the research setting of the consumer study delivers a guideline for future convergence areas to develop a structural categorisation of the borderline products and their estimated consumer acceptance. Future studies might concentrate on the derivation of a more general approach with which to include the consumer perspective into the assessment framework of convergence processes.

In conclusion, the derived assessment framework could be tested in other areas of functional foods. Additionally, because there are various contributions and practical implications for convergence areas in general, this assessment framework could be extended to other convergence areas. As the proposed research framework extends the previous assessment of convergence processes to the later stages of those processes, future studies could further extend the assessment framework to analyse the restart of new convergence processes.

# Summary

The worldwide growing functional food market (e.g. Menrad, 2003, Ding et al., 2015) reflects the convergence of the food and pharmaceutical sectors (Omta, 2004, Bröring, 2005), since functional foods incorporate a nutritional as well as a health benefit (Spence, 2006, Hasler, 2002). The importance of innovation increases, since the emergence of the functional food market implies an intensification of competitive pressure. Due to high failure rates, there is an urgent need to improve the food innovation process (Stewart-Knox and Mitchell, 2003). Various models are used to structure the innovation process, such as for instance the general approach of the Stage-Gate® system (Cooper, 2001) or the cycle of innovation focusing on functional food development (Jones and Jew, 2007) by covering the stages of idea generation and selection, development, product testing, and market launch.

The convergence process is considered to follow the consecutive steps of science, technology and market convergence, leading to a complete industry convergence in which companies or whole industry segments fuse (Curran et al., 2010, Hacklin, 2008). Linking these steps to the simplified innovation process, the comparative perspective on the innovation and convergence processes delivers a framework with which to analyse innovation processes in converging industries using different perspectives. Therefore, the present thesis aims

- **to evaluate the convergence process using different perspectives in order to derive an assessment framework of the innovation process in converging industries.**

This study deals with the functional food sector emerging between the food and pharmaceutical industries while using certain functional ingredients as a measure. Based on the main objective of this thesis, the main research question can be derived focusing on the overall integration of the different perspectives.

***Main research question:***
*How can different convergence assessment perspectives be integrated to derive an overall framework with which to analyse convergence processes at the intersection of the food and pharmaceutical industries?*

The present thesis comprises two parts. It first focuses on the procedural perspective of convergence processes in order to deliver a comprehensive analysis of the complete convergence process. This is then complemented in the second part by a focus on the later steps of market and industry convergence.

**Comprehensive analysis of the convergence process**

This study delivers quantitative (Chapter 2 – life cycle approach) and qualitative (Chapter 3 – perspective of innovation value chain) measures for the comprehensive analysis of the complete convergence process. While the life cycle approach focuses on the development showing the movement of complete industry sectors, the innovation value chain perspective delivers insights into the underlying strategic cross-industry activities on a company level.

Convergence is based on market changes, which can be reflected by life cycle concepts (e.g., Herrmann, 2010, Höft, 1992). Recent literature focuses on the evaluation of the front end of the convergence process (science and technology convergence) by using bibliometric data including scientific publications and patents (Curran et al., 2010, Preschitschek, 2014, Golembiewski et al., 2015). These approaches are mainly used to anticipate converging areas in advance. However, many convergence areas that have been described in the 1990's have already reached the maturity phase (Henderson and Clark, 1990, Katz, 1996, Prahalad, 1998). Consequently, measures to analyse the

changing market environment in the later phases of the convergence process increase in importance for researchers and practitioners alike. The following research questions target this research gap.

***Research question 1.1 (Chapter 2):***
*To what extent can cross-industry activities be depicted in life cycles?*

***Research question 1.2 (Chapter 2):***
*What kinds of life cycle patterns can be identified in the convergence process?*

A bibliometric analysis focusing on probiotics was conducted, drawing upon 8,245 scientific publications, 2,082 patents and 1,357 news reports focusing on product launch announcements from 1990 up to 2009. The results of the analysis indicate that the proposed curve shapes of the life cycles in the theory-based framework can be transferred to the case of probiotics. There is a time shift with regard to the life cycles, showing the same activities of the industry sectors at different moments in time. The food sector dominates the field of probiotics by driving science, technology and market convergence, showing earlier activities in scientific publications, patents and product launches, and presenting a higher clockspeed (measured by the length of the time lags between science, technology and market life cycle). Thus, the dominance of an industry sector in an emerging field can be identified using the life cycle perspective. While the food sector dominates product launches for food products containing probiotics, the pharmaceutical sector dominates the product launches of the supplement market. Thus, the dominance of an industry sector in an emerging field can be based on the proximity of this sector to the market of the emerging borderline products. In addition, a clear trend towards convergence can be identified by the growing number of cross-industry activities. The study in Chapter 2 concludes that the science, technology and market life cycles can be used in innovation management to determine the progress of the convergence process.

The chain and network science perspective is of a high relevance for the structural analysis of industries and the industry developments (Omta et al., 2002), and therefore of convergence processes as an on-going process in many industry fields (Hacklin, 2008). Current studies analysing converging industries reflect the reconfiguration of value chains due to the involvement of companies from different industry sectors (Bröring and Cloutier, 2008). Nevertheless, the refined concept of the innovation value chain (Hansen and Birkinshaw, 2007) has not yet been applied to converging industries. Whereas the study in Chapter 2 provides an overview on industry level by using a quantitative research strategy, the study in Chapter 3 complements this quantitative data by analysing companies active in converging areas their strategic types using qualitative data. Since most studies on convergence concentrate on the industry perspective (Curran, 2010, Preschitschek, 2014, Kim et al., 2015, Golembiewski et al., 2015), Chapter 3 enhances the convergence literature by analysing the company level using an innovation value chain perspective. The study delivers a comprehensive set of indicators to scrutinise the convergence process in order to address the following research question.

***Research question 2 (Chapter 3):***
*How can convergence be assessed using an innovation value chain perspective?*

The study in Chapter 3 encompasses the analysis of four innovation value chains and focuses on different probiotic bacteria strains emerging at the borderline of the food and pharmaceutical sectors, in which altogether 12 companies are active. Different cross-industry relationships occur along the innovation value chains of the four probiotic bacteria strains. Clear signs of science and technology convergence are found as companies are not only publishing and patenting in the area of their own industrial field, but also in the area of the other industry fields. Food and pharmaceutical companies show activities in obtaining health claims, which indicates regulatory convergence. Companies' competence bases seem to converge, as these companies are involved in cross-industry acquisitions, licensing agreements and strategic alliances (competence convergence). This study contributes to the existing body of literature by assessing convergence from an innovation value chain perspective with a set of indicators reflecting the intensity of convergence. This leads to a landscape description of the reconfiguration of innovation value chains. Furthermore, based on the comprehensive set of indicators, the characteristics of the different strategic types can be identified, which drive the convergence process in probiotics.

**Analysis of the later convergence phases**

Next to the comprehensive analysis of the convergence process, this study delivers two levels with which to analyse the later phases in converging industries: first, the analysis of cross-industry collaborations on a company level (Chapter 4), and second, the analysis of ingredient awareness on a consumer level (Chapter 5). While the analysis on a company level delivers an approach to analyse cross-industry innovation using the resource-based view, the consumer perspective sheds light upon the consumers' perception of the products delivered in the convergence areas.

Convergence processes are based on the activity of distinct industry sectors and the companies belonging to this sector (Hacklin, 2008). The emergent market during convergence implies a vulnerable strategic position of the involved companies from different industry sectors. In the context of the RBV (originated in Penrose, 1959), this vulnerable strategic position triggers companies to join collaborations in order to obtain critical resources and competences that enable companies to share costs and risks (Eisenhardt and Schoonhoven, 1996, Das and Teng, 2000, Parmigiani and Rivera-Santos, 2011). Although recent studies relate the theoretical perspective of collaborations to converging industries (Preschitschek, 2014, Sick et al., 2015), there is a research gap in analysing the kinds of cross-industry collaborations using an RBV perspective. Following an exploratory research approach, the longitudinal case study in Chapter 4 analyses cross-industry collaborations of the two leading food (Nestlé/Danone) and pharmaceutical (Martek/Bayer HealthCare) companies. By doing so, the study in Chapter 4 addresses the following research question.

***Research question 3 (Chapter 4):***
*What kinds of cross-industry collaborations can be used to close competence gaps?*

The selected companies are analysed regarding their cross-industry collaborations using the two determinants motivation and industrial scope of collaboration. Many cross-industry collaborative activities emerge at the interface of the food and pharmaceutical sectors. The food companies are more active in cross-industry collaborations than the pharmaceutical companies. The pharmaceutical companies are more active at the front end of the innovation value chain, which focuses on research and development and on delivering their ingredients to food companies that launch the products due to their higher expertise in consumer marketing. The contribution of this chapter lies in delivering an approach with which to analyse the later phases in converging industries based on cross-industry collaborations as a measure to identify the movement of the involved industry sectors. Companies can use this research framework to identify the strategies of competitors, using publicly available data. Based on the identified collaborations, future market fields of competitors can be determined. Furthermore, the identification of the different cross-industry collaboration forms used by companies in convergence enables companies to decide, which collaboration forms fit best the situation.

Because consumer acceptance is a major challenge as well as a key success factor for innovation in functional foods (e.g. Verbeke, 2005, Weststrate et al., 2002), the consumer perspective of the converging industries of food and pharmaceutics is gaining importance. Consumer research in all stages of the innovation process fosters the later market success of the borderline products (Van Kleef et al., 2005). Although previous studies show great interest in consumer acceptance of functional foods, for instance regarding healthy food choices (Roininen and Tuorila, 1999, Urala and Lähteenmäki, 2003, Krystallis et al., 2008), there is a research gap in evaluating ingredient awareness and its determinants. By using structural equation modelling to analyse ingredient awareness and the intertwined relationships of the determinants, the study in Chapter 5 responds to that research gap and answers the following question.

***Research question 4 (Chapter 5):***
*How can convergence be assessed using a consumer perspective?*

A sample of 200 German consumers was interviewed via CATI (computer aided telephone interview) during September 2011. The consumer study in Chapter 5 indicates varying levels of ingredient awareness throughout the sample. Overall, it can be stated that 19% of consumer awareness about functional food ingredients can be explained based on the following predictors: age, educational level, health status, health motivation and information strategies. Among these factors, consumers' health motivation seems to have the highest relevance in explaining consumer awareness. However, the determinants information strategies and education level also show a significant influence on consumers' ingredient awareness. The knowledge about ingredient awareness allows companies to define the target groups for borderline products. Thus, the appropriate communication strategy for these target groups can be derived.

In summary, convergence implies changing competitive environments. The evaluation of this phenomenon is therefore of high importance for researchers and practitioners alike. This thesis enhances the research field of convergence by delivering an overall assessment framework that integrates different perspectives to screen convergence processes and to analyse converging competences. The scope and the unit of analysis, along with the adaptation of theoretical concepts, extend already existing convergence assessment approaches. Besides the analysis of the early phases of convergence processes used to anticipate industrial developments (e.g. Curran et al., 2010), the elaboration of the complete convergence process delivers an approach to face the multifaceted challenges during the innovation process in converging industries. The practical implications of this study is that it provides companies in convergence areas different measures to evaluate convergence processes in order to identify relevant convergence areas. Depending on the phase of the convergence process, the appropriate method or mixture of methods can be used to substantiate strategic corporate decisions.

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# Appendices

## Appendix 1

*Table A-1: Summary of used terminology*

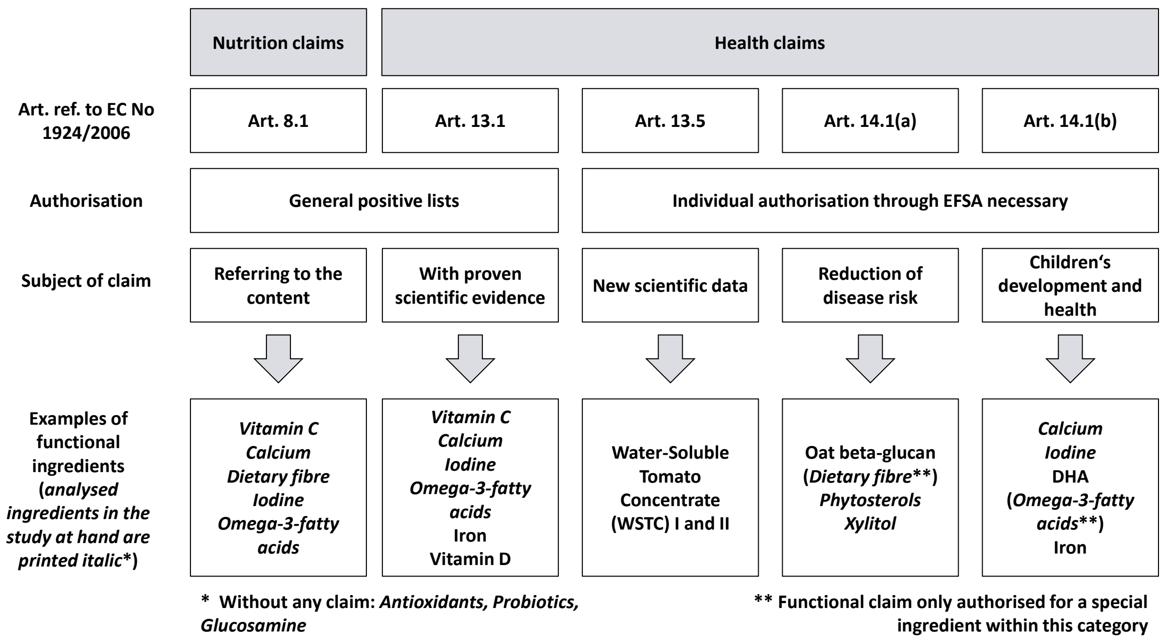
| | |
|---|---|
| **Industrial scope of collaboration** | |
| **Outside-in** | The outside-in process encompasses the integration of resources and competences into the development from other industry sectors. |
| **Inside-out** | The inside-out process focuses on the externalisation of assets towards other industry sectors. |
| **Coupled process** | The coupled process incorporates both the internalisation of external assets as well as the externalisation of internal assets. |
| **Motivation of collaboration** | |
| **Exploration** | Exploration collaborations aim to explore new opportunities focussing on longer-term competitive advantage. |
| **Exploitation** | Exploitation collaborations aim to execute existing knowledge concentrating on short-term commercialisation. |
| **Type of interdependency** | |
| **Reciprocal** | Reciprocal interdependency describes a joint development using resources and competences from both partners. |
| **Discrete** | Discrete interdependence describes collaborations with decisions made independently by the partners |

## Appendix 2

The portfolio (ref. Figure 5-2) showing the choice criteria of the ten functional food ingredients is based on the one hand on the distinct claim types that are possible according to the European legislation (see Figure A-1) and on the other hand the research history described in Table A-1 (Appendix 2).

According to the categorization, the ingredients analysed in the study in Chapter 5 are printed at the lower end of the figure in italic. Also the ingredients without a claim are included in Figure A-1.

*Figure A-1: Chosen ingredients according to the European legislation*



**Appendix 3**

The classification of ingredients is based on the following time frame:

(1) LONG – up to 1900.
(2) MIDDLE – 1900 to 1960.
(3) SHORT – 1960 up to date (so the last 50 years of researchhistory).

*Table A-2: Overview of research history on the ten ingredients to categorise the moment of discovery*

| Ingredient | Description of research history | Classification |
|---|---|---|
| Iodine | 1816 first usage of iodine with treatment of struma | LONG |
| Phytosterols | 1951 demonstration of cholesterol-lowering properties by Peterson | MIDDLE |
| Omega-3-FA | In the 1950s many investigations of effects of corn oil and fish oil on human serum cholesterol concentrations | MIDDLE |
| Calcium | 1808 first isolation | LONG |
| Xylitol | In the 70s – discovery as a possible caries reducing carbohydrate | SHORT |
| Vitamin C | Discovery of treatment of scurvy with fresh fruits (1535) | LONG |
| Dietary fibre | From 1930 on increasing interest | MIDDLE |
| Probiotics | 1908 recommendation of Metchnikoff to use fermented milk products for the treatment of gastro-intestinal diseases<br>In the 50s increased interest in probiotics | MIDDLE |
| Glucosamine | Recent research on possibilities of using glucosamine for prevention | SHORT |
| Antioxidants | Differs for distinct antioxidants | MIDDLE |

## Appendix 4

The questionnaire consists of five parts considering the following topics: firstly, health status; secondly health motivation; thirdly, ingredient awareness of the interviewed consumers; fourthly, the frequency of use of distinct information sources (forming the construct of information strategies), and fifthly, the socio-demographic criteria including age and educational level.

*Table A-3: Items of the questionnaire*

| **Health status – self-assessment** | **Origin of scale** |
|---|---|
| Health status in general | National Nutrition Survey II |
| Physical mobility<br>Mental well-being<br>Self-care | EQ-5D™ |
| **Health motivation – statements** | **Origin of scale** |
| *Statement 1:* I try to prevent health problems before I feel any symptoms.<br>*Statement 2:* I am concerned about health hazards and try to take action to prevent them.<br>*Statement 3:* I don't worry about health hazards until they become a problem for me or someone close to me.<br>*Statement 4:* There are so many things that can hurt you these days. I'm not going to worry about them.<br>*Statement 5:* I don't take any action against health hazards I hear about until I know I have a problem.<br>*Statement 6:* I'd rather enjoy life than try to make sure I'm not exposing myself to a health hazard. | Jayanti/Burns (1998) |
| **Self-assessed ingredient awareness** | **Origin of scale** |
| Iodine<br>Phytosterols<br>Omega-3-fatty acids<br>Calcium<br>Xylitol<br>Vitamin C<br>Dietary fibre<br>Probiotics<br>Glucosamine<br>Antioxidants | Burton et al. (1999) |
| **Frequency of use of different information sources** | **Origin of scale** |
| Health claims on packages<br>Ingredient list on packages<br>Newspaper/magazines<br>Television<br>Radio<br>Internet<br>Consumer service centre<br>Public authorities<br>Recommendations by friends<br>Recommendations by health experts | National Nutrition Survey II and Burton et al. (1999) |
| **Socio-demographic criteria** | |
| Age<br>Educational level | |

**About the author**

Sabine Bornkessel was born in 1981 in Rheinbach, Germany. In 2009 she received her diploma in Nutritional Sciences and Home Economics (ecotrophology) at the University of Bonn. After her study program she worked as a research assistant at the University of Bonn. Since 2010 she has been working as a lecturer at the University of Applied Sciences in Osnabrück, Germany, in the field of technology and innovation management. Through this experience, she developed an interest in the innovation management of functional foods at the edge between the food and pharmaceutical sectors. As an external PhD candidate in the Management Studies Group at Wageningen University (since October 2012), she focused on the assessment of convergence from different perspectives using distinct examples from the functional food sector. She disseminated her research results through several international conferences and workshops; her research was also published, for instance, in Food Quality and Preference. Furthermore, she co-authored a chapter in a teaching book. She was distinguished with a Best Paper Award at the 11th Wageningen International Conference on Chain and Network Management (2014) in Capri, Italy, with the paper titled *'Analysing indicators of industry convergence in four probiotics innovation value chains'*.

**Cover design**

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