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7 Meat processing and animal by-products

Industrial dynamics and institutional settings

Anne Nygaard Tanner and Nhat Strøm-Andersen

7.1 Introduction

In this chapter, we examine the key mechanisms that drive the evolution of the meat and animal by-product (ABP) sector towards a circular bio-based economy. A circular bioeconomy cuts across sectors and industries and includes the production of renewable biological resources as well as the utilisation of side-streams and residues for high-value products in food, feed, bio-based materials, chemicals, cosmetics, pharmaceuticals and energy. Many of the sectors that are relevant for a circular bioeconomy are primary sectors, such as 'agriculture' and 'food, beverage and tobacco', including meat processing and animal by-product industries. In the European Union the 'agriculture' and 'food, beverage and tobacco' sectors combined are currently leading the bioeconomy in terms of turnover (estimated at 75%) and employment (80%) (Ronzon, Santini & M'Barek, 2015).

Although new technologies are a prerequisite for a bioeconomy, technological development alone is not sufficient (Pyka & Prettner, 2018). Transforming industrial sectors is a co-evolutionary process of systemic changes of interrelated elements that, besides knowledge and technology, include actors, networks and institutions (Malerba, 2002, 2005a, 2005b). It is also a highly spatially dependent process, shaped by place-specific factors such as geography and industrial structure (Coenen, Benneworth & Truffer, 2012; Hansen & Coenen, 2014). In this chapter, we focus on the dynamics of the meat processing and ABP sector and the patterns and strategies of value creation that characterise companies in this industry.

The analysis reveals a sector which is highly shaped by its regulative environment, in the sense that regulations decide input and output and define the room actors can manoeuvre within in their search for value creation. Similarly, we find that place-specific factors influence the range of opportunities available for actors in each of the nationally embedded sectoral innovation systems.

The chapter is structured as follows. The following section briefly introduces the theoretical approach the chapter draws upon. Section 7.3 introduces the empirical section with a short description of the inherent and diverse

nature of ABP, followed by a presentation of the industrial characteristics in the two countries in focus for this study, namely Denmark and Norway. Finally, we present the key institutional framework that guides the behaviour of firms in this sector before analysing how meat processing and ABP companies act within these changing settings. Section 7.4 discusses and concludes the main findings in relation to the questions raised in the Introduction.

7.2 Theoretical background and approach

The chapter draws on the conceptual understanding outlined in Chapter 3 that sees innovation as key for the transformative changes towards a circular bioeconomy. It builds on a systemic and evolutionary understanding of socio-economic and socio-technical systems, and their change processes. Sectors such as the meat-processing and ABP industry are formed by a set of activities that are unified by related product groups and share a common knowledge base.

Sectoral innovation systems such as the meat-processing and ABP industry are constituted by different elements such as actors (firms, universities, research institutes, NGOs, consumers, policy- and lawmakers, etc.), knowledge and learning processes, technologies, inputs and demand, networks and institutions (Malerba, 2002). The elements of the system co-evolve over time, resulting in processes of change that enable the transformation of the system. Moreover, rates and types of innovation differ greatly across sectors depending on the level of technological development, institutional settings, market opportunities and processes of selection (Malerba, 2005a).

Taking a systemic perspective implies focusing on the dynamics of sectors or industries, meaning how constituting elements co-evolve over time, rather than static comparisons of industry structures and their performance at a given point in time. In particular, the explanatory focus is on factors and mechanisms that drive these change processes; in other words, it entails understanding the laws of motion for a specific industry.

Furthermore, characteristic for the systemic perspective is its focus on interdependencies and links between related industries. Boundaries of sectoral systems are not fixed but rather change over time. In particular, for the food industry, the vertical links and coordination between different production activities or nodes in the value chain have been shown to play a significant role in the innovative behaviour of firms (Karantininis, Sauer & Furtan, 2010). Historically, the hierarchical market structure of the food industry has often been explained by a relatively weak appropriability regime (Peneder, 2010), meaning the possibility for protecting knowledge and innovations from imitators is low. However, in pace with an increasing innovative behaviour, the market structure of the industry changes, which results in a movement towards vertical integration upstream in the value chain (Karantininis et al., 2010).

Finally, in a sectoral innovation system perspective, institutions play a key role in shaping input and demand, as well as the interactions between market

and non-market actors. Although institutions are most often seen as a stabilising element of the system, they may also play a role in fostering novelty and transforming sectoral systems. In particular, a disruptive change in institutional settings, such as the introduction of a radical change in regulations, fundamentally changes the belief system and established practices of an industry, and potentially leads to changes in innovative behaviour.

In the meat-processing and ABP industry, a major driving force is precisely institutional change in the form of regulations to protect the health of humans and animals. Since the 1990s, regulative changes have become the key mechanism of change affecting and shaping *input* and *demand* of the industry. The main input is defined as side-streams from meat and livestock production. Because of their human and animal health and welfare risk, ABPs are a heavily regulated raw material. The main demand is likewise shaped by market regulations such as trade barriers and sanctions, which is characteristic for agri-food products. Whether trade barriers are supported by arguments of health or environmental reasons or politically motivated as a consequence of a bilateral, diplomatic crisis, trade barriers have huge consequences for the market opportunities of the meat and ABP industry. Together, regulations shape the input and demand of the industry and thereby also influence market opportunities and innovative behaviour of firms in the industry.

The following section will elaborate and exemplify these dynamics through our empirical insights of the meat processing and ABP industries in Norway and Denmark. The analysis builds on 20 interviews: 12 interviews with actors from the industry in Denmark and eight interviews with actors from the industry in Norway. The interviews were conducted from 2015 to 2018 and aimed to cover topics such as the key dynamics of the industry, the historical development and key events of the industry, innovative practice and the development of markets and new products. In addition to the interviews, the analysis builds on secondary material such as EU directives, historical newsletters from interest organisations, articles from news media and reports and secondary literature of the sector.

7.3 The meat processing and ABP industry

The meat processing and ABP industry primarily encompass two types of firms: producers of ABPs and processors of ABPs. The production of ABPs occurs in all the nodes of the meat value chain from animal production, at slaughterhouses, and at the facilities of further meat processors (see Figure 7.1). Processing of ABPs has historically been a task for rendering companies, which are dedicated ABP processors. Rendering companies have played an important role in securing and managing the huge amounts of by-products produced from the meat industry to avoid hazardous risks. Today, dedicated ABP processors include incumbent rendering companies but also new entrants where the focus is also on upgrading specific types of ABPs (e.g., blood, hides and bones) for human consumption.

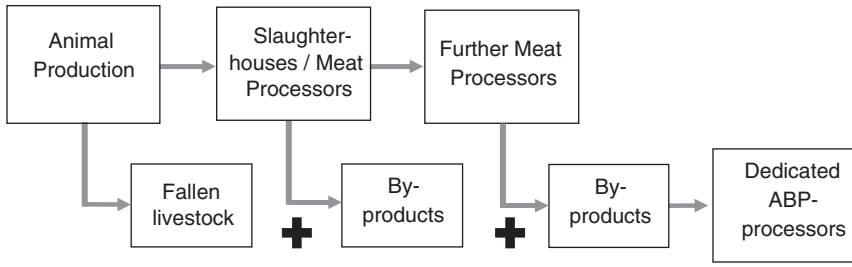

Figure 7.1 The meat processing and ABP value chain. Upper boxes are nodes (firms) in the value chain; lower boxes illustrate the flow of ABPs.

7.3.1 Potential value of ABP

ABPs are materials of animal origin that people do not consume. In the EU, over 20 million tons of ABPs are generated annually from slaughterhouses, plants producing food for human consumption, dairies and as fallen stock from farms (European Commission, 2018). ABPs have an inherently diverse nature, which offers varied possibilities for utilisation and conversion. ABPs contain miscellaneous compounds such as gelatine, protein, enzymes, fatty tissues, collagen and phosphates, which provide manifold possibilities for value-added products and applications through diverse bioprocessing technologies. For instance, animal protein can deliver a complete protein with a high biological value based on its amino acid profile (Mullen et al., 2017). Blood generation often presents a serious environmental issue because of its high pollutant capacity; however, it has exceptional nutritive value and excellent functional properties that give the potential to generate high-added-value food ingredients (Lynch, Mullen, O'Neill & García, 2017). Because of the diversity and heterogeneous nature of ABPs, technical methods that can be applied to valorise meat by-products are numerous and include, for example, ultrafiltration, extrusion, lyophilisation, isoelectric solubilisation-precipitation, solvent extraction and enzymatic hydrolysis (Aspevik et al., 2017; Galanakis, 2012; Mullen et al., 2017). The final choice of application depends on the types of the by-product and the local conditions where the raw materials are generated (Mullen et al., 2017). Local conditions relate, for instance, to the transportation distance from the slaughterhouses to the processing plant, which require methods to keep ABPs fresh for longer to ensure the best quality for further processing. Moreover, the volume of the rest raw materials at the processing plant level has implications for which processing technique is most suitable. In other words, it is not profitable to valorise small volumes of ABPs as this may lead to a negative cost-benefit analysis.

Based on strict regulations, animal by-products are classified into three categories. Category 1 (CAT1) is classified as high risk, including entire bodies and all body parts of the animals associated with TSE (transmissible

spongiform encephalopathy), used for experiments and illegal treatments, infected with diseases and environmental contaminants and specified risk materials (SRMs). CAT1 should be incinerated and only approved combustion plants can receive CAT1 for treatment. Sources of energy such as electricity and biodiesel can be obtained through incineration. Category 2 (CAT2) is classified as high risk, including animals and parts of animals unfit for human consumption such as animals killed for disease control purposes, ABPs containing residues of authorised substances or contaminants exceeding the permitted levels and manure. CAT2 can be incinerated with or without prior processing, converted into organic fertilisers or soil improvers after processing, or used as fuel for combustion. Category 3 is classified as low risk, including carcases and animal parts being left from slaughterhouses, fit for human consumption, but not used due to commercial reasons. CAT3 can be processed to make pet food, or mink food, or utilised in even higher value-added applications in other industries like cosmetics, pharmaceutics or foodstuff.

The meat processing industry has utilised ABPs for centuries. However, recent literature suggests that rich and multiple opportunities exist for upgrading the utilisation of ABPs (see, for instance, Jayathilakan, Sultana, Radhakrishna & Bawa, 2012; Lin et al., 2013; Matharu, de Melo & Houghton, 2016; Mirabella, Castellani & Sala, 2014; Ravindran & Jaiswal, 2016; Toldrá, Mora & Reig, 2016). In a bioeconomy context which aims to shift upwards in the waste pyramid (cf. Chapter 3), this literature shows that ABPs have the potential to deliver on a wide range of products from high-value products to lower-value products such as fertiliser and energy. Figure 7.2 provides an overview.

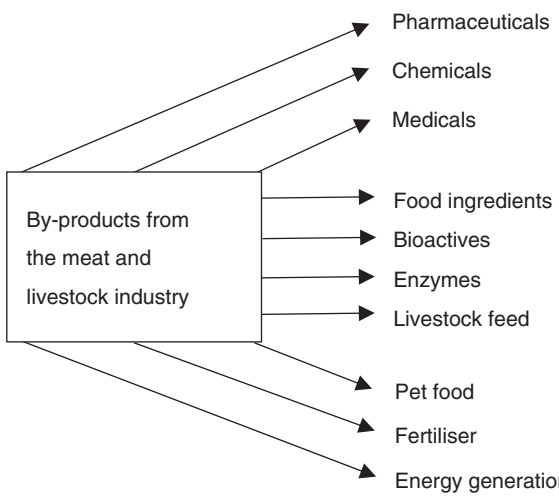

Figure 7.2 Rich and multiple opportunities to upgrade current use of meat by-products (adapted from Toldrá et al., 2016).

According to the waste pyramid, the dominating use of ABPs is characterised by the lowest part of the pyramid, namely recycling, recovery, energy and disposal. Today, the majority of by-products end up in the lowest part, recycled as pet food or feed for animals that do not enter the food chain (e.g. mink), fertiliser or as energy. The top of the pyramid – prevention and reuse – is the most preferable from an economic and environmental perspective (ECA, 2016). The main focus in this chapter is to study how companies in the meat processing and ABP industry facilitate processes of prevention, reuse and recycling of by-products to create higher added value for their resource base (e.g. for human consumption), through process and/or product innovations.

7.4 The meat processing and ABP sector

The meat processing and ABP sector has experienced a strong consolidation and internationalisation over the last 10–20 years, which has resulted in an intertwined network of companies that cuts across national borders. Companies are often connected through interest shares or in supplier–buyer relationships. This is also the case for companies in Denmark and Norway: For example, DAKA (a Denmark-based rendering company) owns 10% of the shares in Norsk Protein; Farmfood receives the majority of the Norwegian poultry ABP (CAT2 material) at their facility in Løgstør in Northern Denmark. Nevertheless, the industry structure and geography of the two countries have a huge impact on the types and volumes of ABPs available in each country, and hence for the basis of input to the industry. In the following, we give a short presentation of the key actors characterising Denmark's and Norway's meat processing and ABP sectors.

7.4.1 Denmark

The meat processing and ABP industry in Denmark is characterised by its very large animal production, especially regarding pigs (see Table 7.1 for a comparison of the size of animal production in Denmark and Norway). In particular, the Danish pig industry is very large compared to Denmark's size and counts approximately 3,300 pig farms that together produce 31.9 million pigs annually (DST table ANI9). Together, the animal production, meat processing and ABP industry comprise 45% (approximately 85,000 people) of the total employment in the food industry in Denmark (Landbrug og Fødevarer, 2017). In 2015, the turnover for the four largest co-operatives in the sector – Danish Crown, Tican, DAT Schaub and DAKA – reached US$10.7 billion (Danish Agriculture & Food Council, 2016). In 2016, Tican became a privately owned company. Key actors in the Danish meat processing and ABP industry are slaughterhouses, dedicated by-product companies, interest organisations, universities and research centres, and more recently, small- and medium-sized technology developers that have entered the industry.

Table 7.1 Animal production in Denmark and Norway (2017 figures)

	DENMARK *Animal production (in brackets, export of live animals)*	*NORWAY* *Animal production*
Pigs (in 1,000 ton)	1,896 (302.3)	137.2
Poultry (in 1,000 ton)	174.4 (39.2)	101.0
Cattle (in 1,000 ton)	135.2 (1.8)	85.2
Egg production (in 1,000 ton)	68	66.7*
Mink fur (1,000 units)	17,900	–
Sheep (1,000 units)	76.5 (0.9)	1,376

Sources: Statistics Denmark: ANI8, PELS1, ANI4, ANI6, ANI5, ANI9; and Statistics Norway: www.ssb.no/jord-skog-jakt-og-fiskeri/statistikker/slakt.

Note
* 2015 numbers, source: www.ssb.no/280562/produksjon-av-kjot-mjolk-egg-og-ull-sa-345.

The Danish meat industry builds on a long history based on cooperative ownership. Ever since the first cooperative slaughterhouse was formed in 1887 in Horsens, the industry has been capable of renewing itself through restructuring. In the 1970s the industry went through a national consolidation driven by technological development that justified larger facilities. In the 1980s consolidation was more market driven, where larger sizes made it easier to access new and larger markets (Tüchsen, 2014).

In the last 15–20 years, the restructuring of the sector has been characterised by European consolidation and internationalisation of markets (Hansen, Egelyng, Adler & Bar, 2015). Today the industry in Denmark is characterised by four to five large slaughterhouses (>500 employees) and around 100 smaller (1–50 employees) ones.

Danish Crown is one of the largest meat processors in the world. It is collectively owned by farmers in Denmark and is responsible for 80% of all pigs and 50% of cattle slaughtered in Denmark. TICAN was acquired by the German slaughterhouse Tönnies and is responsible for around 10% of pigs slaughtered in Denmark. Danpo is part of Scandi Standard, which is a leading producer of chicken-based food products in the Nordic region, with headquarters in Sweden. Danpo is responsible for the majority of chickens slaughtered in Denmark. Finally, Skare Beef and Himmelandskød each slaughter around 15% of cattle in Denmark. Slaughterhouses have recently intensified their interest in valorisation of by-products by engaging in the restructuring of their production facilities and establishing subsidiaries dedicated to handle ABPs. One example is Danish Crown Ingredients, founded in 2014, and Farmfood A/S, founded in 2003 (owned by Danpo, BHJ and HKScan). The vertical integration of business areas related to processing ABPs indicates that the industrial structure is changing in order to protect knowledge, innovation and new market opportunities.

In addition to slaughterhouses and meat processing companies, dedicated by-product processors include DAKA (part of the German Group SARIA)

and BHJ (part of LGI Group). These are also a result of the cooperative movement and have roots that date back to the beginning of the 1900s. During the last decade, dedicated by-product companies have likewise diversified by founding subsidiaries with a focus on specific types of ABP as a strategy to increase the value of ABPs. For example, BHJ's subsidiary Essentia Protein Solutions has its main focus on food ingredients produced from Category 3 material. Essentia produces functional proteins to improve the functionality, taste and nutritional character of food products. DAKA has built similar business areas within ingredients, pet food, biodiesel, organic fertiliser, etc.

The two main interest organisations representing the industry's interests in Denmark are the Confederation of Danish Industry and the Danish Agriculture and Food Council, which also comprise SEGES, a research and innovation centre for agriculture and the food industry in Denmark. However, more importantly for the internationalised Danish industry is the European Fat Processors and Renderers Association (EFPRA) that lobby for the industry's interest at the EU level.

Finally, a low number of new technology developers have entered into partnership with some of the larger players in the industry to demonstrate and develop their technologies. These include, for instance, Lihme Protein Solutions, Dacofi and Upfront Technology.

It is difficult to estimate the exact volume of ABPs in the Danish industry. Based on our interviews we estimate >500,000 tons of ABPs are produced and handled in Denmark. Danish Crown produces 375,000 tons of ABPs per year. Besides this, Farmfood handles 140,000 tons of poultry by-products from Denmark, Sweden and Norway (including 80% of Norwegian ABPs). Interviews with actors in the industry disclose fallen volumes of ABPs, which results in increased competition on ABPs. For example, DAKA has recently (August 2018) closed their smallest processing facility because of reduced volumes of blood. The decreasing volumes are caused by new valorisation paths of ABPs (e.g. mink food and ingredients); an increasing export of live animals (e.g. piglets); and an increasing sale of products that were previously Category 3 material but are now sold to Asian markets (e.g. pig ears, gallstones).

7.4.2 Norway

The meat processing and ABP industry is the biggest sector by employment (25%) and the second largest sector by revenue (21%) in the Norwegian food and beverage industry (2016 statistics presented in Prestegard, Pettersen, Nebell, Svennerud & Brattenborg, 2017). All Norway's meat consumption is covered by Norwegian producers, with the exception of some beef that is imported duty-free from Botswana and Namibia. The sector is organised by a few large companies and a number of small- and medium-sized enterprises, with a total of 319 companies. In 2016, the sector had a revenue of US$6.1 billion and 11,477 employees (Prestegard et al., 2017). The key actors in

Norway are meat processing companies, rendering companies, the meat and poultry confederation and research centres.

Nortura is Norway's largest meat and egg producer, and is collectively owned by Norwegian farmers. The company is a major player in the food industry in Norway, which accounts for 70% market share (2014 data collection). Nortura has more than 30 slaughterhouses spread all over Norway. Nortura's total production/slaughter tonnage is 428,900 tons a year (2014 data), in which cattle account for 78,100 tons; lambs and sheep 23,600 tons; pigs 128,500 tons; eggs 94,100 tons; and chicken and turkey 104,600 tons. Its daughter company, Norilia AS, is in charge of handling by-products generated from all Nortura's slaughterhouses, which are considered to be 35% of the entire production (approximately 150,000 tons). Nortura has two other daughter companies – Norsk Hundefor AS and Norsk Dyremat AS – that produce pet food from ABPs for international and domestic markets, respectively. The rest of the meat processing industry is composed of a few medium-sized companies such as Norsk Kylling AS, Fatland AS, Grilstad AS and other small private companies.

Norsk Protein AS is the only rendering company in Norway that receives by-products from slaughterhouses and meat processing companies, specified risk materials (SMR) and dead animals. The company has five production plants (three plants for CAT3 and two plants for CAT1) receiving ABPs from all over Norway, distributed in four locations from north to south, namely Balsfjord, Mosvik, Hamar and Grødaland. There are no CAT2 plants in Norway, so CAT2 is sent to CAT1 treatment plants, and partly to Denmark. In accordance with current regulations in Norway and the EU, the company further reprocesses the CAT3 raw materials to meat and bone meal (MBM), and animal fat. Norsk Protein AS was established in the 1970s, and is currently owned by Nortura SA (67%), the Norwegian Confederation of Meat and Poultry (KLF) (23%) and DAKA Denmark AS (10%) (KLF, 2016). Norsk Protein received a total of 197,831 tons of rest raw materials from slaughterhouses in 2017 (Norsk Protein, 2017). Norsk Protein is also represented in EFPRA, the European interest organisation for rendering companies.

Other actors that play an important role in the industry network are the Norwegian Confederation of Meat and Poultry (KLF) and the Norwegian Meat and Poultry Research Centre (Animalia). KLF, founded in 1910, is an interest and industry organisation that represents the privately owned, free-standing part of the meat, egg and poultry industry in Norway. Animalia is Norway's leading research and development specialist in meat and egg production, providing knowledge and expertise through domestic animal inspections and veterinary health services, business-critical technical systems, research and development projects, e-learning and training activities, communication and other forms of knowledge-sharing. On January 1, 2018, Animalia left Nortura SA as a separate limited company. Animalia AS is now owned by Nortura SA (66%) and the Federation of Meat and Poultry Industries (KLF) (34%). Previously, the company was organised as a department in Nortura.

Because of the geographical characteristics of the country, slaughterhouses in Norway are small and scattered, which makes it difficult to collect and handle ABPs. Valorisation of ABPs involves the entire process of developing new business areas in markets and technologies, in which meat and ABPs companies have somewhat limited knowledge and experience. For example, to enter the international ingredient markets for human consumption (proteins and fats), Norwegian meat companies encounter a series of challenges related to, for instance, market entrance, distribution channels and brand reputation. The industry is aware of many new, potential technologies that can be used to process ABPs. However, it takes time to learn, acquire and select the right ones given the inherently diverse characteristics of ABPs. In addition, developing innovation is costly. Lack of risk capital funding is another issue that challenges the industry in commercialising research results. Despite these drawbacks, the ABP industry in Norway is strategically seeking higher value markets.

Summing up, the key difference between Denmark and Norway can be characterised by the word size. With almost the same population size yet Norway's land area being seven times that of Denmark, the population density is much higher in Denmark (131/km^2) than in Norway (15.5/km^2). To cover the vast area of farmland slaughterhouses in Norway are smaller and scattered across the country, whereas in Denmark slaughterhouses are fewer in number and much larger. Taking Denmark's smaller size in area into the equation, ABPs are more easily collected and transported in Denmark.

It is not only differences in the two countries' geography that influence the input and hence the possibilities for value creation, but also the industrial size and structure. Primarily, Denmark's pig production is one of the largest in Europe and the two slaughterhouses Danish Crown and Tican (Tönnies) are among the largest in Europe. Company size in terms of finances, geographical markets and volumes of meat and ABPs are important for the value creation strategy, in particular in terms of possibilities to finance new initiatives and to access the right volumes and type of ABP input. Hence, the larger volumes and easier transportation of ABP in Denmark place the Danish industry in a better position to create and utilise new market opportunities.

7.5 Regulation of the meat processing and ABP industry

To understand valorisation of ABP, it is important to acknowledge that it is a heavily regulated field. Interviewed actors in the industry unambiguously mention regulations as the key influential factor shaping the industry. EU laws and directives regulate both *inputs* to the industry in terms of types and volumes of ABP and the *demand* and market opportunities primarily through export bans and import barriers, as well as through regulations on nutritional and health claims on novel food products (see Figure 7.3). Indirectly, these

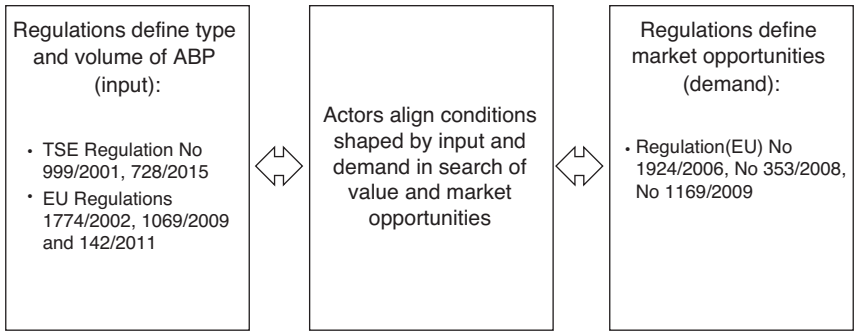

Figure 7.3 Value creation dynamics in the meat processing and ABP industry.

regulations also shape interactions between market and non-market actors as well as the practices of companies guiding innovative activities and strategies in search of new market opportunities.

7.5.1 Mad cow disease and EU-regulations

The historical background of the main regulations on the input side dates back to the outbreak of 'mad cow disease' (i.e. Bovine Spongiform Encephalopathy, BSE) in the mid-1980s, which proved to have far-reaching consequences for the industry. As a result, besides huge economic losses and the killing of millions of animals, it culminated in very comprehensive regulations on the handling and use of animal by-products, which disrupted the whole industry, and today permeate everything the industry is doing. The consequences were huge for the UK economy and the animal production industry. It is estimated that 180,000 cattle were affected and 4.4 million cows were killed during this period. By comparison, in Denmark only 15 cows with BSE have been detected along with three incidents in cows exported from Denmark.

In 1986, the first incident of BSE was diagnosed in the UK, although it is believed the disease had existed for several years prior to this. Investigations at the time showed that the spread of BSE occurred through the feed produced at rendering companies. Infected animals, either alive or fallen stock, were sent to the rendering factories and used in the production of MBM, which was used in feed to cattle and other livestock. Consequently, this cycle multiplied the spread of BSE across the UK.

The connection between BSE and the human variant, Creutzfeld-Jacobsen Disease (CJD), was not discovered until 1996. Consequently, from the late 1980s and until the early 1990s it was believed that there was no human risk from eating beef infected with BSE. However, in March 1996 when the first announcement about a possible link between BSE and CJD was made, it

resulted in a total import ban on UK beef and cattle to the rest of Europe. The ban was only lifted in 2006. To date, 177 people have died because of contracting the human variant of BSE.

In 1990, the first EU regulative ban on using ruminant MBM in feed for ruminants was introduced. It was a way to inhibit the further spread of BSE by breaking the vicious cycle. In 1994 this ban was expanded to concern protein feed from all animals (including pigs, poultry, etc.) to ruminants. In 2001 the EU imposed a total ban on using any remains of all animals in feed for livestock (TSE Regulation No 999/2001). The TSE Regulation No 999/2001 was introduced throughout EU as well as in Norway from January 1, 2001 (Nærings- og fiskeridepartementet & Landbruks- og matdepartementet, 2004, 2016). The main argument was that feed for ruminants was too easily contaminated during production, storage or transportation with MBM produced as feed for pigs and poultry. Hence, it was assessed to be a risk that ruminants would be fed with ruminant proteins. Consequently, the total ban on using any animal by-products in feed for any animals was a means to meet the human health risk of consuming beef.

From one day to the next it changed the market situation for the whole industry. In Denmark, this caused a huge bottleneck in the system. DAKA, which was the main purchaser at this time, experienced their previous market for animal feed being disruptively shut down overnight. This resulted in an accumulation of 180,000 tons of MBM at DAKA with no potential purchasers. As a result, the product totally lost its value, which sent the company out in search of other markets and a process of restructuring and reorganising its business.

Also in Norway, the sudden introduction of the TSE Regulation yielded a significantly higher price than alternative solutions such as landfill, combustion or fertiliser. This new regulation changed the price of MBM accordingly from a positive value of NOK 2–3 per kg to a negative value of NOK 2–3 per kg overnight. Similarly, in Denmark, interviewees report that they had to pay the incineration and cement industry 600–700 DKK per ton. The negative prices for the rendering companies were imposed on the slaughterhouses that delivered raw materials to rendering companies.

In 2002 another set of regulations was introduced in the EU (EU Regulations 1774/2002, later replaced by EU Regulations 1069/2009 and 142/2011), which regulates the use of animal by-products throughout the entire food chain. This set of regulations introduced the categorisation of ABP in three categories, CAT1, CAT2 and CAT3, introduced in section 7.3.1.

7.5.2 Market regulations: novel food products and trade barriers

Another type of regulation is the EFSA's regulation (European Food Safety Authority) on nutrition and health claims (Commission Regulation (EU) No 1924/2006, No 353/2008, No 1169/2009). In order to protect consumers, health claims need to be justified scientifically. The EFSA regulation places

high requirements on the labelling of, for example, functional food products. In practice, this means that, in order to make use of health claims on new products, the claim has to be proven by clinical trials similar to the pharmaceutical industry, which is assessed to be too costly in time and resources for companies in the food industry.

Trade with ABP and food products is highly regulated. Traditionally, food products have been included in trade barriers and sanctions supported by arguments of health or environmental reasons. Trade barriers are also often politically motivated as a consequence of bilateral, diplomatic crises, and turn out to have huge consequences for the market opportunities of the meat and ABP industry.

An example is the geo-political crisis between Russia and EU that resulted in, on August 6, 2014, a Russian decree prohibiting, for one year, imports into the territory of the Russian Federation of certain agricultural products, raw materials and foodstuffs originating from EU countries, Norway, USA, Canada and Australia (European Commission, 2017). The embargo was later extended until August 5, 2016, and then further prolonged until December 31, 2017 (European Commission, 2017).

This important event led to price fluctuations on the international raw materials market, and significantly impacted the industry on its rest raw materials base. Products on the banned list included meat of bovine animals; pork, poultry meat and edible offal in all forms (fresh, chilled or frozen); sausages and similar products of meat; meat offal or blood; and the final food products based thereon (European Commission, 2017). For example, while Nortura used to export large quantities of ABPs to Russia, after the ban it was forced to find other solutions, and to search for valorisation alternatives.

7.6 Change in innovative behaviour

This section analyses how companies navigate the highly regulated space we have outlined above. The question is how companies approach market opportunities and different market segments based on the institutional settings which regulate the type and volume of input and not least the market options. Figure 7.3 illustrates part of the regulative space which sets the overall framework of the meat processing and ABP industry.

For slaughterhouses, the introduction of the TSE regulation and the categorisation of ABP types led to increased attention being paid to the processing and collection of ABP. In the first period after the new regulation was introduced, the main activities aimed to optimise slaughtering processes and reduce losses at the slaughterhouses to increase the overall value of ABP. As a result, a significant amount of CAT1 material was upgraded to CAT3 with a much higher value. In Denmark, the Technological Institute assisted the Danish industry in optimising, sorting and collecting ABP, so the different categories of ABP materials were kept apart. If any CAT3 or CAT2 materials were in contact with CAT1 material, this would devalue the material to

CAT1. Similar process innovation took place in the Norwegian meat and ABP industry.

Rendering companies also changed their innovative practice in the years that followed the introduction of ABP regulations. They focused on organisational, process and product innovation. At the least, larger rendering companies had to restructure their production facilities to run three separate streams of material (CAT1, CAT2 and CAT3) at different plant sites. CAT1 was prepared as MBM for incineration, CAT2 had to be sterilised before being used as fertiliser and CAT3 principally found a use as pet food.

In both countries process and product innovation is still an ongoing activity characterising valorisation of ABP. For instance, Nortura collaborates with SINTEF and other research centres to optimise meat cutting and minimise waste. The process of distinctly categorising ABP and organic side-streams into different groups for optimal treatment and further processing enables more flexible and sustainable food processing. Furthermore, the company attempts to better organise process innovation by developing cooling systems at slaughterhouses and during transportation to keep the raw materials fresh.

Product innovation has been given attention where the industry seeks higher value-added applications. Norilia recently launched two innovation projects: eggshell membrane extracted and provided to the medical industry for wound treatment, and protein in various forms and applications obtained from enzymatic hydrolysis technology in a biorefinery opened in 2018. At the same time, another company, Norsk Kylling AS, has also established an enzymatic hydrolysis plant to utilise its by-products. Processing by-products to high value-added applications and products such as protein has proven to be a crucial strategy for the industry.

7.7 Regulative adjustments

As stated above, the EU regulations on ABP introduced in 2001 (amended in 2015) following the BSE scandal condition the type and volumes of *input* to the ABP industry. This also means that if this law is changed, the input foundation of the industry changes. A highly regulated field such as the meat and ABP industry provides strong incentives for the industry to engage in institutional entrepreneurship (Dorado, 2005; Leca & Boxenbaum, 2008). This occurred in 2015 when the definition of the specified risk material (SRM) in the TSE regulation was amended based on a scientific opinion published by the EFSA (2014). With this change, a large amount of bovine intestines (approximately 30 kg per cow) was moved from the SRM list (i.e. CAT1) to CAT3 material. As a consequence, the volumes of CAT3 material increased significantly and caused a significant drop in prices.

This situation threatened the European rendering industry and their interest organisation, EFPRA, started lobbying for expanding market opportunities of processed animal proteins (PAP), including lifting the export ban of PAP. Originally, the export ban of PAP was to hinder PAP from also

being used in animal feed outside the borders of EU. However, the argument EFPRA put forward was that the EU had the strictest regulations in the world and whether or not EU rendering companies export PAP to be used in animal feed, PAP is used anyway in animal production outside Europe. Therefore, to assist the industry in creating a market for PAP, the EU agreed to lift the export ban on PAP. Likewise, the EU has assisted in creating new markets as a result of industry players' lobbying activities, such as allowing PAP in aqua feed.

7.8 Conclusion

This chapter has analysed the co-evolutionary development of the meat processing and ABP industry in Denmark and Norway from a sectoral innovation system perspective. We have shown how the value creation strategies of firms co-evolve with institutional change, input and demand, organisational changes and knowledge and technological development.

In particular, institutional changes in the form of regulations have a huge impact on the strategies of firms in value creation processes. First, the EU regulations on ABP introduced in 2001 after the BSE scandal condition the type and volumes of *input* to the ABP industry. Second, we demonstrate that temporary trade barriers such as import/export restrictions between countries influence the market creation possibilities, and hence the *demand* for meat- and ABP-based products. These temporary import boycotts therefore have a huge impact on price formation in the industry and influence market dynamics. As a result, actors align the conditions shaped by input and output in their search for new valorisation paths and market opportunities.

Second, we conclude that differences in the two countries' industrial structure and geography influence the input and hence the possibilities for value creation in different ways. Primarily, Denmark's pig production is one of the largest in Europe and the two slaughterhouses Danish Crown and Tican (Tönnies) are among the largest in Europe. Because of Denmark's small size in area, ABPs are more easily collected and transported to customers or processing facilities. By comparison, the slaughterhouses in Norway are smaller and scattered across the country. Company size in terms of finances, geographical markets and volumes of meat and ABP is important for the value creation strategy – in relation to possibilities to finance new initiatives and to access input as well as the technological options for efficient processing technologies. In summary, the industrial structure, size and geography of the two compared countries put the Danish industry in a better position to create and utilise new market opportunities.

Finally, in relation to our initial question of how the meat processing and ABP industry can contribute to a circular bioeconomy, we see diverging trends. During the last couple of decades, the valorisation of ABP has returned to the centre stage of the global meat industry. Slaughterhouses are increasingly interested and active in processing ABPs, which puts pressure on

the supply of raw materials for meat processors and dedicated ABP processors. Another tendency is that new processors have entered the value chain and dedicated by-product processors have been forced to change focus and secure their supply of raw-materials because of increased competition.

The increased interest for valorising ABP is nevertheless faced with decreasing volumes of ABP in Denmark, partly because of a higher degree of utilisation of the animals and partly because of an increased export of piglets and live animals to Germany and Poland. The latter has consequences for the number of slaughtered animals at slaughterhouses in Denmark, which naturally drops when the export of piglets and live animals increases. The other cause, a higher degree of utilisation of the slaughtered animals, is a consequence of companies being able to sell new types of cuts to new markets (for example, pig ears, gallstones, etc. to Asian markets), which also causes a natural drop in volumes of ABP. This has, overall, led to higher competition of the remaining ABP, and prices have therefore gone up.

However, increasing prices for ABPs provide companies with incentives to utilise ABPs to a higher value. Likewise, the EU regulations on ABPs and the categorisation of by-products have caused meat processing and ABP companies to improve the utilisation of ABPs, which has led to a change in innovative behaviour. Prior to the introduction of the regulation in 2001, the industry did not innovate in relation to the use of ABPs. However, as we have argued in this chapter, the regulation caused meat processing and ABP companies to change innovative behaviour, resulting in new processes and products valorising ABPs. Put together, it is our assessment that the changes the ABP industry has faced during the last couple of decades and their interest in embracing the political agenda of circularity provide industry actors a strong incentive for valorising ABPs, adding to a circular economy.

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