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A Study of the Danish Agriculture, Forestry and Fishery Industries

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Research Paper

Patterns and Collaborators of Innovation in the Primary Sector: A Study of the Danish Agriculture, Forestry and Fishery Industry

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ABSTRACT Based upon a large-scale survey and case studies of innovation we explore patterns of innovation activities in the Danish agricultural, forestry and fishery industries. Our primary focus areas are the sources and capabilities of innovation. We demonstrate that despite the fact that this industry is often regarded as low-tech there are still substantial innovation activities going on. Around 23 per cent of the 640 firms surveyed had product and/or process innovation, 24 per cent had other types of innovation. A total of 46 per cent had some type of innovation. Firms delivering directly to end-users were more likely to be innovative than those delivering to the processing or wholesale links of the value chain. Many of the innovative firms had no collaboration on innovation, and respondents generally claim that stimuli for innovation were primarily internal. We also demonstrate that the industry has a very well developed extended knowledge base, which is a vital source of information and knowledge for innovation. This may explain why traditional survey instruments do not fully capture the external sources of innovation.

KEY WORDS: Innovation, agriculture, knowledge sources

1. Introduction

Even though a large share of the current economic and political discourse is heavily emphasizing the “knowledge-based economy”, the primary sector and affiliated manufacturing industries maintain a significant role for exports and employment in several highly industrialized countries. In Denmark, these activities have a large share of total

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employment and exports. Twenty per cent of total Danish exports are from these industries. Despite this position, the sector has received relatively little attention regarding its innovation capacity and future development potential.

Studies of innovation in this industry remain sparse. The few studies on these industries have focused on food processing (e.g. Boon, 2001; Baker, 2007; Christensen, 2008). This paper focuses on the patterns of innovation in the other and equally important parts of the activities, namely, the agriculture, forestry and fishery industries (in the following denoted the AFF industry) in Denmark. Denmark is an interesting case as its agri-food industry is known to be competitive and innovative.

Studies of innovation in AFF are particularly important in the present era. In many countries the industry is under heavy economic pressure. In Denmark, the average farmer has a debt of 3 million euro and negative income (Fødevareøkonomisk Institut, 2010). It is projected (ibid.) that one out of four farms will disappear in the next five years. This scenario may call for sustained and perhaps increased productivity gains through innovations. However, continued reliance on increases in productivity through optimization of processes has been the dominant model, but may be a dead end. It could be hypothesized that more radical changes and product innovations are needed. The paper contributes to knowledge on different types of innovation in the AFF industry. This is particularly interesting in a Danish context as the Danish production model is characterized by intensification, mechanization and large-scaling (Manniche and Kjeldsen, 2010)¹ as well as vertical integration and cooperation (Baker, 2007). The pressure for innovation is claimed to be substantial throughout the value chain. Less than half of all new food products are on sale one year after their introduction, and limited shelf space puts a pressure on innovations higher up the value chain (ILO, 2006). It is likely that the product life cycle for food products will continue to be reduced, which further increases the demand for innovation in the AFF industry and in other parts of the value chain.

Some of the main findings from studies of innovation in general have emphasized that collaboration and external knowledge sourcing is essential for innovation. Moreover, that literature has found that innovation differs substantially across industries and size of firms (Dosi, 1988). The present paper explores the patterns of innovation and collaboration in the AFF industry. We study how size, proximity to cities, type of customers and type of AFF activity influence the likelihood of innovation. This gives us valuable insight into how innovation takes place in this industry and into the degree to which different sub-industries (such as cultivation, market gardening, end-user producers, etc.) innovate. We also study how these different factors influence the degree to which innovation is undertaken with other partners. We employ both quantitative methods by means of a large-scale survey and a qualitative approach using case studies of specific, innovative firms. Thus, we contribute to the literature both by identifying drivers in the AFF industry dynamics and by providing a quantification of innovation activities in the industry.

The paper is structured as follows: Section 2 reviews established knowledge on innovation in the industry. Section 3 provides a framework for the empirical analysis and explains the context in which the study is conducted. The data are also described in that

¹ According to the statistical analyses in Manniche and Kjeldsen (2010), there are no systematic general indications of a change away from this "productivist" production paradigm.

section. Analyses of these data are presented in Section 4. The fifth section provides an additional perspective on the results, as it discusses the underlying knowledge base and institutional set-up of the industry. Conclusions and perspectives in terms of further analyses are rounded up in Section 6.

2. Literature Review

Innovation is important for firms facing transformation pressures (Lundvall, 2002), and the academic literature on innovation has been constantly increasing (Fagerberg, 2005). One important perspective in the literature is to perceive innovation as an interactive process (Kline and Rosenberg, 1986; Lundvall, 2007). Even though most innovations depend on knowledge and learning processes within individual firms, most innovations also benefit from knowledge sources embedded in the firms' external, systemic context (Nelson, 1993; Stoneman, 1995). Firms interact with and learn from other firms, suppliers, customers, universities, knowledge organizations and other government organizations, and relations of interactive learning may be institutionalized in innovation systems (Lundvall, 1992; Edquist, 1997; Sharif, 2006).

As in other industries, the innovation process in food processing is still more inter-organizationally interactive and depends upon several different types of knowledge bases (Christensen *et al.*, 1996; Smith, 2000; Alfranca *et al.*, 2001, 2004). This complicates innovation studies, but accentuates the need to take a broad approach. Scholars have argued that using an innovation system approach more widely as an analytical framework is useful not only when studying the manufacturing part of the food and drink industry but indeed also for studies of the agricultural industry (Hall *et al.*, 2003; Hall, 2005). The Danish AFF industry is characterized by extensive systemic institutionalization of knowledge generation with strong knowledge diffusion institutions. Therefore, we assess the innovative activities in the AFF industry from a systemic point of departure.

The application of the system of innovation framework to the AFF industry has several implications. First, because innovation is primarily understood as emerging from individual actors interacting in an institutional context, it is of prime interest to explore which actors are important for the innovation process, how they have interacted and collaborated with other actors in the process, and how the institutional setting has affected the process and outcome. Second, the framework implies focusing on how learning as well as production, dissemination and use of knowledge have supported the innovation process. Both of these implications stem directly from the fundamental characteristics of the framework as stated above.

In pointing to the importance of knowledge dissemination and learning, the system of innovation framework is complementary to the absorptive capacity literature (Cohen and Levinthal, 1989, 1990). R&D and other knowledge building activities may increase the absorptive capacity of food firms. However, as most innovations in the industry are incremental due to inertia in consumer demands a low level of R&D may be sufficient to secure an adequate stream of innovations (Galizzi and Venturini, 2008). In the Danish AFF industry the institutionalization and dissemination of knowledge among actors in the industry have made much of the relevant knowledge easily accessible. There is, however, a need for a carrier of dissemination. This implies that not only absorptive capacity is important for efficient learning and knowledge dissemination; also the actors involved in the process are

important. Thus, we both have to investigate these external stimuli to innovation empirically and we need to interpret the findings in an institutional context.

It has been found that important types of knowledge (e.g. tacit knowledge), learning and innovation have a geographical, localized dimension (Maskell and Malmberg, 1999; Gertler, 2003; Asheim and Gertler, 2005). This directs our attention to the geographical concentration of innovation, and there is evidence from studies of food processing that the geographical location affects innovation (Avermaete *et al.*, 2003). The innovation system literature provides a link between the sources of knowledge and partners for innovation on the one hand and on the other the spatial dimension of these partners and knowledge. In turn, innovation is likely to be stimulated by geographical proximity. Large retailers, research centres and consultative organizations are often located in larger cities. Following this it may be argued that the capacity for innovation increases if firms are located in close proximity to such organizations (Christensen, 2008). Moreover, previous studies (Præstholt and Kristensen, 2007) have indicated so-called peri-urban dynamics, meaning that some new firms in both production and services/suppliers have established themselves near large cities where demand is greater; in the Danish context this means around Copenhagen. This is likely to increase the innovative probability of firms located in or near larger cities.

It is well established in innovation studies that large firms are more often innovative than small firms. Although firm size in this industry may be difficult to define precisely,² the relative size of firms still influences internal knowledge capacity, which in turn may result in less demand for external advice. Related to the size of the firm the possibilities of benefitting from complementary assets (Teece, 1986) may be crucial for incentives to embark on innovation at all in the food industry. According to studies in the food and beverage industry³ (Galizzi and Venturini, 1996) the marketing and advertising activities are vital for successful innovation but may be possible to pursue only for larger firms. In AFF industries distribution channels may be added to the list of necessary complementary assets. Using a resource-based view of the firm, Grande *et al.* (2007) find strong evidence of a correlation between size and entrepreneurial orientation and performance in Norwegian farm-based ventures. Thus, the likelihood of innovation generally increases with firm size.

A further aspect of innovation patterns relates to how far the producers are from the market. In virtually all innovation surveys the customers are regarded as the primary source of innovation (e.g. Christensen *et al.*, 1996). However, the customer may be in different parts of the value chain. Producers in the AFF industry may deliver to wholesale, retailers or directly to end-users. Grunert and Traill (1997) find that close links to retailers stimulate innovation. Similarly, Senker (1987) see the retailers as drivers of innovating food products because they are better capturing signals from end-consumers. We therefore also investigate if selling to end-users benefit innovation.

In sum, we hypothesize that:

²By nature the number of employees in different segments of the industry varies a lot, and may also be highly dependent upon seasons. It may be argued that the revenues would be a better size indicator. The statistics on turnover are, however, highly incomplete.

³See Rama and von Tunzelmann (2008) and Galizzi and Venturini (2008) for overviews of empirical studies on the relationship between size and innovation in food and beverage firms.

- Innovations are dependent upon collaboration and are embedded in a broader innovation system;
- Geographical location matters to innovation;
- Size of the firm is positively correlated to innovation;
- Innovation activities may be more or less intense depending upon the primary consumer.

3. Empirical Approach

The empirical approach of the paper is twofold. First, we seek to explore some general patterns of innovation activities in the Danish AFF industry based upon a large-scale survey analysis. Second, we seek to complement the exploration of the more general patterns of innovation activities with qualitative case studies. The function of the case studies is, thus, to supplement the data found in the survey and the interpretation of these data.

3.1 Empirical Context

One reason why relatively little empirical evidence exists on innovation in Agriculture, Forestry and Fisheries (AFF) may be that the conceptual understanding of innovation is better elaborated in the manufacturing industry, rendering higher validity of surveys. Another reason may be that it is often presumed that this industry is not very innovative, so innovation researchers have shown little interest in surveying this industry. On the other hand, in a knowledge-based, internationalized economy even seemingly low-tech and traditional industries need front-end knowledge to stay competitive, and the Danish AFF industry is known to be competitive in spite of the fact that Denmark has relatively high wages. This indicates that there must be some innovative activities going on. Likewise it is known that the industrial part of the Danish agro-industrial complex does introduce innovations and rely heavily on improvements in processes and quality control.⁴ Earlier studies indicate that innovation has an impact on performance in the broader food production industry, including the AFF industry (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2003). The pressure for innovation stems not only from increasing requirements to meet safety and quality regulations and the demand for environmentally and animal welfare friendly models of production. It also stems from the general increase in competition pressure.

Regarding manufacturing activities of the food industry, innovation includes specific renewals such as new types of additives, flavours and conservation, new forms of logistics and new forms of packaging. Innovation in the AFF industry, on the other hand, includes new crops, flowers, methods of fishing, fodder, pesticides, methods of harvesting, breeding, tracking systems, etc. Such preliminary reflections on innovation have important implications on understanding innovation in the industry.

First, innovation in the AFF industry differs from innovation in food processing. This means that innovation in the AFF industry is not necessarily easily incorporated in the traditional, manufacturing-oriented conceptual and empirical classification of innovations. Second, even when focusing on the AFF industry, innovation is an ambiguous phenomenon.

⁴Recent studies (Manniche and Kjeldsen, 2010) indicate that despite tendencies to new types of production and distribution this model generally persists.

This clearly challenges any conceptualization of innovation and any attempt to survey innovation activity in the AFF industry.

Our approach to surveying innovation activity in the AFF industry distinguishes broadly between product innovations and process innovations. These are defined in line with the Oslo manual and as being new-to-the-firm developments. Recognizing that other types of changes than new products and processes may be important, we ask the firms if other changes were implemented, such as new forms of organizations, ownership, marketing or sales methods. Based on this basic distinction, the survey then continues through a stepwise specification of what the renewal is and how it was developed. Following this approach, we attempt to improve empirical knowledge on innovation in the AFF industry, and compare this knowledge with some of the main findings in the traditional, manufacturing-oriented classification of innovations.

3.2 Data and Methods

The quantitative analysis is based on data from a telephone-based survey on innovative activities in the AFF industry. The Danish AFF industry consists of 8,520 firms with one or more employees of which 372 firms have 10 or more employees. Traditionally, innovation surveys such as the CIS only target firms with more than 10 employees, but the AFF industry consists of a majority of very small firms, especially within agriculture. Therefore, we approached all 372 firms with 10 or more employees as well as a stratified sample of the smaller firms. We stratified with an emphasis on larger firms (5+) and did not include firms with less than two employees. All firms were interviewed in September and October 2007 concerning their innovative activities of the past two years. A total of 1,283 firms were contacted, of which 2 per cent were not a firm, and 11 per cent did not have activities in the AFF industry. Forty-two per cent of the 1,113 remaining firms did not want to participate in the survey, which results in a response rate of 58 per cent.

The Danish AFF industry is dominated by agriculture, which accounts for 90 per cent of the employment. Therefore, fishing and forestry entails a limited number of firms in our realized sample. Moreover, some of the firms are service firms related to the industry rather than to the production of primary goods. In order to ensure a sufficient number of observations in the empirical analyses and to produce more coherent sub-industries, we re-classify the industries on the basis of similarity of activities. We split up the AFF industry into five sub-industries: cultivation, farming, market gardening, service and fishing. Cultivation comprises the cultivation of crops, fruits, nuts, spice crops and mixed farming. Farming comprises the farming of cattle, sheep, goats, horses, donkeys, mules, hinnies, pigs as well as poultry and dairy farming. Market gardening comprises the growing of vegetables, horticultural specialities and nursery products, landscape gardening and forestry and logging. Service comprises agricultural and animal husbandry service activities and forestry and logging-related service activities. Fishing comprises fishing, fish farming and related service activities.⁵ Table 1 shows the distribution of the population and sample by size and industry.

⁵ Cultivation is defined as NACE 11110, 11190, 11300 and 13000. Farming is defined as NACE 12110, 12190, 12210, 12300, 12400 and 12510. Market gardening is defined as NACE 11210, 11220, 14120 and 20100. Service is defined as NACE 14110, 14190 and 20200. Fishing is defined as NACE 50100 and 50200.

Table 1. Population and respondents

	1 employee	2–4 employees	5–9 employees	10+ employees	Total
<i>Total population</i>					
Cultivation	1,489	552	150	49	2,240
Farming	2,791	1,271	215	35	4,312
Market gardening	393	342	226	227	1,188
Service	162	141	91	56	450
Fishing	199	109	17	5	330
Total	5,034	2,415	699	372	8,520
<i>Respondents</i>					
Cultivation	–	53	45	13	111
Farming	–	183	77	10	270
Market gardening	–	39	72	52	163
Service	–	21	40	18	79
Fishing	–	7	8	2	17
Total	–	303	242	95	640
Share of population	–	0.125	0.346	0.255	0.075

Source: The population is based on data from the NN erhverv database.

The respondents were asked whether they alone or in collaboration with others have converted to a different production or initiated additional production of products that are new to the firm, that is, product innovation. Similar questions were asked concerning processes. However, it is likely that the respondents considered these questions to deal only with larger and more significant innovative activities. In order to also cover smaller projects and other types of changes that may perhaps better capture innovation in this industry, we asked whether they have engaged in development activities that were not directly new products or processes, but rather changes in organization, sale, distribution or other types of innovations.

Following the questions regarding innovation activity, the innovating respondents were asked whether they collaborated with external partners regarding product and process innovations. In regression analyses, we investigate the factors that characterize firms that innovated alone or collaborated with customers, competitors or technical and knowledge organizations other than universities. Since the sample is stratified, we add weights based on the total population of firms.

The respondents were also asked whether their products are primarily targeted towards end-users, trade (wholesale or retail), manufacturing (food and beverages processing) or other. As a result it is possible to investigate if firms selling to end-users are more likely to innovate compared to firms that deliver to trade or the manufacturing industry.

The qualitative case study includes five innovating AFF firms operating within market gardening (fruit and special vegetables) and fisheries, which had 2–35 employees. The description of the innovation process in each firm builds on desk research and semi-structured in-depth interviews with one or more informants in each firm with key knowledge of the firm's innovative activities. The market gardening firms were located in the southern part of Zealand, which is a relatively peripheral region, while the fishing firms were located in Northern Jutland, which is the most fishing-intensive region. The firms were

chosen on the basis of desk research in branch magazines and interviews with key informants in the regional industry and advisory system. The case study innovations were all new products belonging in the higher end of the price spectrum. In general, the innovations were perceived incremental by the consumers but more radical to the individual firm as regards type of production, production methods or organization of production process as well as sales or distribution.

4. Empirical Analysis

4.1 Survey

The distribution of the realized sample is: cultivation (17 per cent), market gardening (26 per cent), primary industry services (12 per cent), farming (42 per cent) and fishing (2 per cent). The firms are divided into three groups according to their primary customer base. Forty-five per cent of the weighted sample mainly delivers to the manufacturing industry (food processing), whereas 30 and 23 per cent deliver to trading firms (wholesale and retail) and end-users, respectively.

Our overall indicator of innovation shows that 46 per cent has introduced some type of innovation in the previous two years (Table A1 in the Appendix presents the descriptive statistics on our survey variables). This includes product innovation (23 per cent of firms), process innovation (23 per cent) and other unspecified types of innovation (24 per cent).

There is a 9.6 per cent overlap of firms introducing product and process innovations, see Figure 1.

Only 5.2 per cent of respondents are listing all three types of innovations. “Other innovation” are most commonly mentioned. These include organizational change, sales, distribution and other types.

We address the characteristics of regions by including a dummy variable for regions with a major city (more than 40,000 inhabitants). Twenty-three per cent of the firms in the sample are located in a region with a city of this size.

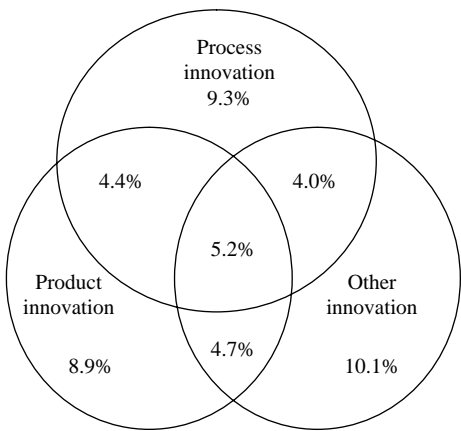


Figure 1. Types of innovation

Fifty-eight per cent of the innovative firms have not collaborated with partners, while 12 per cent have collaborated with competitors, 26 per cent with technical partners and 18 per cent with users (see Table A2 in the Appendix). The most frequent technical partner is private technical consulting companies and laboratories (19 per cent) followed by test, control and standardization organizations (14 per cent) and other independent Danish research and technology organizations (7 per cent). In addition, 26 per cent of the innovative firms collaborate with suppliers, 18 per cent with non-technical consultants and 9 per cent with universities. Thus many of the innovative firms collaborate with various partners. The respondents were also asked who took the initiative to innovate. Seventy-seven per cent responded that the initiative was their own; the remainder of the possible sources were only listed by a small (3–5 per cent) share of the respondents.

We regress on the likelihood that firms have innovated in the previous two years. The benchmark in our regressions is farming and fishing (combined). The results (four regressions) are shown in Table 2. The first regression has our overall innovation indicator as the dependent variable. The next three regressions have the three underlying type of innovation indicators as dependent variables.

Across all models, we find that larger firms (more than 10 employees) are more likely to innovate than smaller firms. Cultivation, gardening and services firms are more likely to innovate compared to farming and fishing firms.

We find that cities have different effects on the likelihood of innovation, depending on which indicator we are looking at. Firms located in bigger city regions are more likely to introduce process and product innovations, but they are less likely to engage in unspecified innovations. Similarly, firms primarily targeting end-users and trading sectors are more likely to innovate compared to firms mainly selling to food manufacturing firms.

Overall, these findings meet our expectations. Larger firms and firms in the more advanced cultivation, gardening and service sections of the AFF industry are more likely to innovate. This effect is increased, however, if firms supply directly to end-users and trade, that is, retailers. Proximity to major cities has no effect on the probability that the firms will be innovative at all.

Table 3 shows the regressions on the innovators in our sample. These regressions have different types of partnership as dependent variables and address the effect of our explanatory variables on if they innovate alone or with a partner. Secondly, the type of collaborating partner, such as customers, technical partners or competitors.

We find that smaller firms are significantly more likely to innovate alone compared to firms with more than 10 employees. Firms targeting end-users and the trading sector are less likely to innovate alone, but are more likely to choose a partner for innovation. The same relationship applies to firms located near major cities. There might be a barrier for collaboration on innovation, which smaller firms have a harder time overcoming. Larger firms are perhaps better equipped for devoting time for collaboration and for absorbing knowledge from external partners.

The next three regressions of Table 3 show the likelihood of choosing specific partners for innovation. Not surprisingly, larger firms are more likely to innovate with technical partners and customers than are smaller firms, which show an overall preference for larger firms as partners in innovation. Firms targeting end-users are significantly more likely to innovate with customers and competitors than firms targeting manufacturing outlets. Firms located near major cities are also more likely to innovate with competitors.

Table 2. Logistic regression on innovation (weighted)

Dependent variable	Innovation (yes/no)		Product innovation		Process innovation		Other innovation	
Variables	Parameter estimate	SD	Parameter estimate	SD	Parameter estimate	SD	Parameter estimate	SD
Intercept	0.420***	0.056	0.114**	0.059	-0.534***	0.061	-0.351***	0.061
Size > 10 (vs. < 10)	0.294***	0.027	0.256***	0.028	0.261***	0.028	0.278***	0.027
Cultivation (vs. farming & fishing)	0.159***	0.029	0.272***	0.034	0.098***	0.032	0.249***	0.032
Market gardening (vs. farming & fishing)	0.175***	0.035	0.301***	0.038	-0.017	0.037	0.190***	0.037
Service (vs. farming & fishing)	0.112**	0.047	0.363***	0.049	-0.065	0.052	0.002	0.052
End-users (vs. manufacturing)	0.110***	0.034	0.150***	0.037	0.087**	0.037	0.086**	0.037
Trade (vs. manufacturing)	0.099***	0.028	0.184***	0.033	0.101***	0.031	0.019	0.032
City (vs. no)	-0.021	0.027	0.085***	0.029	0.054*	0.029	-0.057*	0.030
Observations	640		640		640		640	
Concordant	64.1		71.3		60.4		64.7	
Likelihood ratio	318.605***		455.190***		140.480***		265.031***	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3. Logistic regression on collaboration on innovation (weighted)

Type of partner	Alone		Customers		Technical		Competitors	
Variables	Parameter estimate	SD	Parameter estimate	SD	Parameter estimate	SD	Parameter estimate	SD
Intercept	-0.022	0.078	-0.286***	0.090	-0.597***	0.083	-0.900***	0.101
Size > 10 (vs. < 10)	-0.077**	0.034	0.051	0.040	0.155***	0.036	0.066	0.044
Cultivation (vs. farming & fishing)	-0.195***	0.043	0.370***	0.057	0.058	0.046	0.189***	0.058
Market gardening (vs. farming & fishing)	0.057	0.048	0.338***	0.062	0.011	0.051	0.098	0.063
Service (vs. farming & fishing)	0.076	0.065	0.431***	0.075	-0.070	0.070	0.020	0.086
End-users (vs. manufacturing)	-0.262***	0.047	0.167***	0.055	0.082*	0.050	0.195***	0.061
Trade (vs. manufacturing)	-0.132***	0.042	0.022	0.054	0.004	0.045	0.100*	0.057
City (vs. no)	-0.054	0.038	-0.043	0.047	0.015	0.041	0.085*	0.049
Observations	304		304		304		304	
Concordant	58.3		66.3		55.6		60.1	
Likelihood ratio	74.297***		120.056***		28.896***		39.762***	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4 shows the percentage of firms in each sub-industry that primarily target end-users. It reveals that 75 per cent of the firms in the service industry and 43 per cent of the firms in market gardening are primarily delivering to end-users. It is not surprising that these are close to the end-users. None of the very few fishing firms in our sample are primarily targeting end-users. A larger share of large firms is targeting end-users, except for cultivation, where a larger share of the small firms is primarily selling their products to end-users.

The lessons learnt from the multivariate analysis of the survey data are that larger firms located close to major cities are more likely to be innovative. This is a similar behaviour to that of traditional manufacturing firms. In that sense, AFF industry firms are not very different from manufacturing firms. The share of product or process innovative firms in AFF is lower than manufacturing. In the 2006 innovation survey by Statistics Denmark, 41 per cent of the respondent firms in manufacturing had product or process innovation during 2004–2006, while the 2007 survey revealed that 34 per cent innovated during 2005–2007. Size plays an important role for innovation, and since our firms are typically smaller than average compared to firms in manufacturing, this might be an explanation of the lower innovation scores. A larger share of the AFF firms collaborated on innovation (42 per cent) compared to 34 per cent of the manufacturing firms in 2004–2006. Size is also important for collaboration on innovation in manufacturing.

In addition, an important finding of our study is that firms targeting segments closer to the end-users are more innovative compared to other firms. This indicates that the innovative motivation could be affected by the proximity of the firm to the end-user in the value chain. These firms are also more likely to be open towards collaboration on innovation in general and with customers in particular. If we look at AFF industry firms delivering to the food manufacturing industries, they score relatively lower than other firms. It seems if the largest innovative motivation in these value chains is not in primary production, but in the processing segments closer to the end-users.

4.2 Qualitative Studies

The central themes in the case studies were the external knowledge sources in the innovation process, especially the collaboration. The main purpose was to develop and qualify the findings of the survey.

Table 4. Percentage of firms primarily targeting end-users by sub-industry and size

	Small (size < 10)	Large (size > 10)	Average
Cultivation	24.3	17.5	22.1
Farming	6.6	15.1	8.2
Market gardening	39.4	47.2	43.4
Service	75.0	74.8	74.9
Fishing	0.0	0.0	0.0
Total	22.7	38.2	28.4

Note: Weighted percentages.

The use of external knowledge sources was present in all interactive innovation processes but the importance of the knowledge sources changed between the initiation, the development and the production phases.

In line with the findings from the survey, most informants claimed that their innovation was initiated from within the firm, as a result of a more or less explicit search for new products or types of production. In two cases the idea was initiated by direct requests from the market. In many companies, the internal initiation should be seen in light of a generally strong market-orientation in the early phase.

Despite the declared internal initiation, a close look shows that this may stem from the fact that knowledge of needs and possibilities is created from collaboration and interaction with the market and/or the advisory service system. The initiation should therefore be seen in light of the producer's embeddedness in the market and the advisory systems, where the knowledge diffusion is only partly conscious, another part is more tacit and embedded in the geographical local area (Asheim and Gertler, 2005) or in sectoral or value chain communities.

In the development phase of the innovation, most firms described the intensive use of advice from consultants. The gardening companies used the established advisory service (Danish Agricultural Advisory Service) in their normal production, as described in Section 5. The system is strongly established in giving advice on more general topics or general products, while it seems to be less important giving advice on the innovative processes of niche products. In this phase, the most important external knowledge providers were consultants with highly specialized knowledge within the specific product or method. They were independent consultants with contacts to specialized producers or research institutions or suppliers in other countries (in two of the cases seed suppliers). Later in the production phase of the innovation process the general agricultural advisory service seems to gain importance, as they provide the framework for well-functioning "networking groups" among the fruit producers: groups who meet to share experience.

The selected innovation cases demonstrated a much higher level of collaboration with external knowledge providers in the development and production phases than indicated in the survey—in line with the expectations developed in Section 2. In the development phase, highly specialized technical advisors, independent consultants and suppliers turned out to be the key providers of knowledge. They held specialized knowledge and functioned as gatekeepers to international researchers and firms. In none of the innovation cases research institutions were the direct driving force. In this phase, knowledge sources in the sector or value chain seemed much more important than geographical local sources.

Throughout the process the firms seem to have much closer interaction with the advisory system than indicated by the survey. Despite declining importance in the development phase, the cases indicate a continuous input of knowledge from the advisory system in regard to general production, advice on minor product adjustments, networking groups, and as a source of general information and education. This indicates that the advisory service system might be a partly invisible actor in innovation in market gardening, when the focus is on the process or firm level only, whereas it can also be seen in a systemic perspective as proposed by Lundvall (2007).

The case studies do not reveal if firms delivering to retailers are more likely to be innovative. The main part of the production from the firms was sold via wholesale. But it is remarkable that most agricultural firms simultaneously also sold a part of the production

directly to the retail sector or to end-consumers (in “farm shops”). The producers describe this contact to the market as the “fun” part and they appreciate the feedback on products. The “fun” in farm shops can be seen as a classification outside the real farming activity (Clark *et al.*, 2010). At the same time the existence of these activities indicates that they are possibilities of alternative farming/AFF activities and innovation outside the trajectories of the last 50 years of dominant mass production. The farm shops and direct sale can be seen as a strategy which allows the firm to keep selling to the food processing industry while also gaining advantages from close relations to the end-users in the form of market knowledge of innovations. The importance of knowing the market can be seen in the fishing firm. A skipper started an at-sea processing (freezing shellfish into retail packages), which was new to Danish vessels at that time. This process innovation led to a new product. The innovation was initiated by the skipper, but introduced in cooperation with the processing industry, which still handled and sold the products. This innovation was successful (marketable with higher prices), whereas a later attempt to use the same technology for freezing fish failed, as marketing was not established before the product introduction.

In relation to the survey findings, the case studies primarily develop and qualify the findings regarding collaboration on innovation. The firm informants had the same understanding of internal initiation of the innovations as seen in the survey. But the case studies reveal that the internal initiation may stem from knowledge of needs and possibilities which is created from collaboration and interaction with the market and/or the advisory service net. The initiation should therefore be seen in the light of the producer's embeddedness in the market and the advisory systems, where the channels of knowledge diffusion are only partly conscious.

Several of the firms studied do not seem to target either manufacturing or end-users, but to hold a dual strategy where they sell the main part to manufacturing, but keep contact to the end-user market, which provides them with input for innovation. Such a strategy can in itself also be seen as an example of the innovative activity besides the product and process innovation, a part of the “other innovation” activity found in the survey. This illustrates the importance of connections to the end-user market as stated by Rama and von Tunzelmann (2008).

5. Discussion—The Institutionalized Knowledge Infrastructure of the AFF Industry

Although we used both quantitative and qualitative methods, we still miss an important part of the knowledge infrastructure in our analyses that is the original sources of knowledge used for innovation. Even if the number of specific empirical studies is limited, there is growing recognition that most industries rely on knowledge generated in the periphery of the industry itself. In seemingly low-tech industries like agriculture and food processing the majority of innovations may be based upon incremental, practise-driven progress, but nevertheless in some cases substantial parts of their innovations may be based on scientific knowledge (Christensen *et al.*, 1996; Smith, 2000; Wixted and Cozzens, 2007). There is a need for more empirical work mapping these “knowledge ecologies” as denoted by Wixted and Cozzens (2007).

In our survey, direct collaboration with universities and other research institutions were modest. At a first glance one could think that this indicates that the innovation system is not

very important. This needs to be substantiated by analysing whether the knowledge inputs may be of a more indirect character.

The Danish AFF industry, especially the agricultural industry, has a long tradition for organization of the producers.⁶ This has resulted in dominant cooperatively owned processing industries within slaughtering, dairy, feeding stuff and seeds, and there is a strong tradition of vertical integration of the different parts of the value chain of the industry. This tradition and trend have unfolded alongside a trend of horizontal concentration. In addition, different branches of the organization represent the interests of the industry vis-à-vis the political system and have been active in developing a knowledge system to support the production and innovation system of the industry as well as an extensive range of public programmes to support innovation in the AFF industry. This knowledge system is important for both supporting short-term operation and long-term development within education, consulting and research. Below we discuss these three sub-systems to illustrate the broader innovation system and to show how indirect knowledge may diffuse and be important to the innovation system. The latter type of knowledge is, to a large extent, tacit to the respondents in the survey but may be more tangible in the following institutional analysis.

5.1 Education

More than half of the labour force in the AFF industry holds at least a formal technical education of two or three years of school and practice. In the agricultural industry, which is the dominant part with regard to employment, there is an institutionalized system of agricultural colleges, and more than half of the labour force has a formal agricultural education as trained farmers (3½ years of training) or a four-year education required to qualify for “the green certificate” (Statistics Denmark, 2006). A “green certificate” is needed to achieve the right to own and run a farm of 30 hectares or more. Generally, the education level in the Danish agricultural industry is relatively high compared to qualifications required in order to be a farmer in other countries. This contributes to ensuring that production is pursued efficiently and in accordance with standards for environmental protection and animal welfare, and it provides a basis for uptake of science-based advice from the research and advisory systems. Even if this is an important feature of the agricultural sector, at the same time it is a fact that a large share of workers in the sector has no formal education. Many are foreign workers, especially from Russia, Ukraine, Poland and other Eastern European countries, and they often have no experience from the agricultural sector. They work, though, under the management of Danish, educated managers.

In the fishing industry a three-week course is obligatory before starting work as a fisherman. In order to be authorized to have command of a vessel, the fisherman has to have further education. A two-year basic training programme (of which 1½ years is training on different vessels) qualifies the fisherman for the “blue certificate”, and the right to command minor vessels up to nine metres. A further 1½ years of education (skipper exams) qualifies the fisherman for having command of all vessel sizes (fisheries circle). The educational

⁶ There is also a long tradition for stimulating innovations. For example, in 1769 The Royal Danish Housekeeping Society (an association for farm owners) was established. One of their achievements was to institute prizes for farmers who invented new ways of raising crops or found new products.

system is relatively new, as only 290 have obtained the blue certificate since 1996, and the general educational level among fishermen is low (Holm, 2009). Partly due to a relatively high average age among the fishermen, still a relatively large number of fishermen only hold the mandatory short course certificates on health and security.

In forestry, one of the main institutions in both education and research (and some consultancy) is Forest & Landscape Denmark. This institution stems from a merger in 2004 between the Danish Forest and Landscape Research Institute, Danish Forestry College, the Danida Forest Seed Centre and the Department of Economics and Natural Resources at The Agriculture University, KVL. It is now merged into Copenhagen University and has 300 employees. The educations offered range from short vocational training courses to a PhD school. In between these extremes, there are educations as skilled forest craftsman, forest and landscape engineer and a master programme in forestry.

5.2 Consulting

Complementary to education, consulting is a means of disseminating knowledge to the AFF industry. Especially the agricultural industry has a well-developed consultancy system, organized by the organization Danish Agriculture and Food Council, of which most Danish farmers are members either via a local farmers' association or a regional association of family holdings. Danish Agriculture and Food Council handle the interests of the farmers in business and professional matters, including advisory services and supplementary training. Danish Agriculture institutionalizes diffusion of knowledge on agricultural issues by publishing a weekly magazine as well as Internet-based information. Further, Danish Agriculture and Food Council is the owner of the Danish Agricultural Advisory Service (DAAS), which is a partnership of 46 local advisory centres and a national centre with approximately 3,500 professionals employed. The advisory centres, which sell their services to the individual farmer, are scattered regionally with specialization areas according to the regional needs.

The knowledge diffusing system is much less developed in the fisheries industry. A few (up to 10) fisheries consultants are employed in local branches of The National Danish Fishermen's Association, which organizes most of the Danish fishermen—skippers as well as crew. These are primarily funded by national public means (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2008). Other consultancies are conducted on a project basis by private business consultants, by consultants from the Approved Technological Service (GTS) system,⁷ or by the fisheries-related research institutions. Statistics on landings are well developed as a central element of monitoring and control of resource use.

In forestry, some of the consultancy work is undertaken by Forest & Landscape at Copenhagen University. Another main player is the Danish Forestry Extension, which is a dedicated consultancy service for forest owners. It dates back more than a hundred years and within the last two decades it has extended its services to other countries, especially third world and central/eastern European countries. It comprises 65 advisors in eight local branches and earned revenues of DKK 300 million in 2007. A related institution is the trade

⁷ GTS, Advanced Technology Group, is a group of independent Danish research and technology organizations.

organization The Danish Forest Association, which promotes the commercial and political interests of forest owners. Knowledge dissemination is further carried out through “Information Services” at Forest & Landscape. This is a monthly service informing subscribers of recent research, consultancy and events such as courses, fairs and conferences. Another major player in forestry and in fact in related areas such as trade with forest products (e.g. selling 800,000 Christmas trees annually), green areas and landscaping, watercourse management and organic waste, is the consultancy firm HedeDanmark a/s whose activities span several countries such as the Baltic countries and Germany. This firm was established 140 years ago and has expanded to become the largest player in several areas within forestry, including counselling and services related to specialized machinery. Finally, the statistics on forests in Denmark is well developed. Forest & Landscape is responsible for these statistics, which cover information on volume of land covered by forest in Denmark, types of trees, their age, size and growth rates, and the yields, health and use of forests.

5.3 Research

Finally, the institutionalized systems of education and consulting are complemented by a system of research developing new knowledge and validating knowledge. More general food-related research mainly takes place at four universities, Copenhagen University, Aarhus University, Danish Technological Institute and University of Southern Denmark. The research is coordinated by the Centre for Advanced Food Studies. In 2005, the faculties and centres at the four universities had over 500 scientific staff members conducting research and taking care of higher, research-based education. The research covers a broad range from pure natural sciences as microbiological and chemical food security, health, food technology and food quality, to food-related consumer behaviour.

The agricultural industry also has its own research centres for generating and disseminating knowledge (Landbrugsraadet, 2005). One example is the Danish Meat Research Institute, which functions as a research and development department of the branch organization Danish Meat Association by developing machinery for optimization and automation in abattoirs.

In fishery, research is conducted at the universities, mainly at the DTU Aqua, National Institute of Aquatic Resources and to a lesser degree in departments of relevance to fishery at other universities. The main part of the research focuses on biological assessments of stocks. This research feeds into the common European monitoring system, which is central for the EU management of fisheries under the “Common Fisheries Policy”, with conservation of the stocks as its central problem. Minor parts of the public research focus on economic and technical development of the fisheries, such as new technology and fishing gear.

Research on forestry is primarily at Copenhagen University, Forest & Landscape. The research on forest and forest products includes forest genetic resources, forest planning and monitoring, environment, Christmas trees and greenery. Both the research and PhD projects are often of an applied nature. Consequently, they involve cooperation with a number of organizations and land/forest owners.

The institutionalization of the knowledge generation and diffusion system is probably mostly developed in agriculture and to some degree in forestry, less so in fisheries. Still, all three sub-systems are likely to have important influence on innovation. The specific and precise impact of these systems on innovation is difficult to estimate and difficult to capture

in surveys. It is, though, likely that enhanced coherence of the systems will increase innovativeness. Moreover, relations to other related sectors may have similar effects. For example, it was found in forestry innovation studies (Kubeczko *et al.*, 2006; Ramatsteiner and Weiss, 2006) that in a number of Central European countries the forestry industry has only loose connections to related industries and research institutions, and knowledge flows are consequently underdeveloped. The coherence of the Danish forestry innovation system seems more developed than in the above-mentioned studies, though. The above account of the knowledge generation and diffusion system re-emphasizes the relevance of applying an innovation system approach to studies of innovation in the industry.

6. Conclusions

The aim of this paper has been to explore the prevalence of innovation and innovative behaviour in the AFF industry and how this is related to explanatory factors such as collaboration, external knowledge sources and other characteristics of the firm. On the basis of the results, our overall judgement is that innovation patterns in this industry are in some respects rather different from those found in other industries, and are at the same time, in other respects, somewhat similar to innovation in manufacturing.

Even if this industry is often thought of as being mainly “supplier-driven” and having a low level of innovation, we still found in our survey data that almost half of all respondents, 46 per cent, claimed to have implemented some kind of innovation. Generally, other earlier studies in manufacturing and services found that 40–50 per cent of firms introduced innovation in terms of new products or processes.⁸ The product and process innovation activities in AFF do not indeed match that, but we did find that 23 per cent of firms had such innovation and, in addition to this, other types of innovation (such as organization, sales and distribution) were found to be important for many respondents (24 per cent).

Searching for underlying explanatory factors we found that firm size in terms of number of employees is significantly influential to the majority of our results. This is in accordance with findings from other industries. Besides, in accordance with other literature findings we argued that major cities were the cradles of innovation and innovation collaboration and presumed that Euclidean distances matter for the accessibility of these organizations. We found that there is indeed an increased likelihood of innovation in firms located within close reach of these major cities, but only in the case of new products or process innovations. In the case of other types of innovation this did not apply. From this may be speculated if these other types of innovation make up a development potential for peripheral regions.

Basically our explorative analysis of survey data indicates that innovation in the AFF industry is somewhat similar to innovation in other industries when it comes to the influence of firm size, and partially similar as regards location. But the prevalence of product and process innovation activities does not seem to match that of the manufacturing and service industries.

Contrary to our expectations, we did not find external collaboration and direct external knowledge sources to be very important for innovation in the AFF industry. The majority,

⁸ In the 2005–2007 survey, the share of product and process innovative firms dropped to 34 per cent for manufacturing and 28 per cent for all firms. Various innovation surveys from Statistics Denmark can be found at www.dst.dk/fui

77 per cent, claimed that their innovation activities were initiated by themselves rather than external actors from other links in the value chain. Complementarily, more than half (58 per cent) of respondents had no collaboration on innovation. The external inputs for innovation processes were, thus, not as significant as we had expected. This was also partly found in the qualitative case studies. However, the level of collaboration was higher than for the manufacturing industry. In addition the AFF firms that collaborated on innovation often used multiple sources. Some of the latter (non-) findings in the survey analysis are, however, to be evaluated in the light of the qualitative, case-based findings in the paper.

In Denmark, the knowledge related to the AFF industry is heavily institutionalized in a well-established and widespread knowledge system, and even though our survey results did not confirm directly the importance of this external system for the innovation in the industries, we still have some reservations about this finding. The institutionalized knowledge system might be such an integrated part of the primary producers' knowledge base that they do not consider it to be "external" knowledge. This interpretation is supported by findings in our case studies, which on the one hand confirmed that innovation processes are often initiated in a more introvert manner than we expected, but found, on the other hand, that the companies are part of and make use of a larger system both in regard to the initiation of the innovation process and in regard to knowledge sources in the innovation process. The case studies reveal that innovating primary producers were oriented towards market potentials, and there were some indications that the close interaction between a farmer and the knowledge system in the dominant agricultural part of the AFF industry provided important "indirect" external knowledge and context for the innovations. This type of interaction might lead to implementation of systemic innovations, but is not recognized as collaboration-based innovation by the farmer. Consequently, the importance of the external knowledge source and interactive collaboration is not recognized. Equally important, these incremental, systemic innovations might not even be recognized as innovations by the primary producers as revealed by a supplementing study by Mølgaard (2009).

Compared to the size and importance of the AFF industry, there is remarkably little knowledge on innovation in these industries. This paper provides a first explorative step towards enhanced understanding of innovation in these industries.

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Appendix

Table A1. Descriptive statistics and correlation matrix for innovation (weighted)

Variable (N = 640)	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Product innovation	0.232	0.986	1													
Process innovation	0.228	0.981	0.242	1												
Other innovation	0.240	0.997	0.244	0.208	1											
Innovation	0.465	1.165	0.589	0.584	0.602	1										
Size > 10	0.257	1.021	0.250	0.182	0.221	0.246	1									
Cultivation	0.215	0.960	0.052	0.057	0.105	0.055	-0.037	1								
Market gardening	0.228	0.980	0.214	0.061	0.133	0.166	0.278	-0.284	1							
Service	0.082	0.643	0.113	-0.005	-0.004	0.051	0.120	-0.157	-0.163	1						
Farming	0.437	1.159	-0.259	-0.104	-0.178	-0.205	-0.278	-0.461	-0.479	-0.264	1					
Fishing	0.038	0.444	-0.069	0.022	-0.051	-0.024	0.017	-0.103	-0.107	-0.059	-0.174	1				
End-users	0.229	0.982	0.159	0.047	0.104	0.124	0.188	-0.065	0.274	0.367	-0.352	-0.077	1			
Trade	0.295	1.066	0.112	0.062	0.036	0.082	0.050	0.067	0.259	-0.168	-0.199	0.047	-0.353	1		
Manufacturing	0.447	1.162	-0.269	-0.125	-0.151	-0.206	-0.245	-0.007	-0.475	-0.166	0.506	-0.017	-0.489	-0.582	1	
City	0.231	0.985	0.059	0.034	-0.021	0.001	0.036	-0.121	0.163	-0.071	0.031	-0.078	0.026	0.012	-0.036	1

Note: Bold values are significant at the 0.05 level.

Table A2. Descriptive statistics and correlation matrix for collaboration on innovation (weighted)

Variable (N = 304)	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Alone	0.577	1.143	1													
Users	0.175	0.879	-0.538	1												
Competitor	0.258	1.012	-0.689	0.483	1											
Technical	0.117	0.743	-0.425	0.351	0.393	1										
Size > 10	0.372	1.118	-0.069	0.099	0.117	0.063	1									
Cultivation	0.239	0.987	-0.131	0.071	0.026	0.057	-0.065	1								
Market gardening	0.303	1.063	-0.002	0.091	0.039	0.066	0.206	-0.370	1							
Service	0.098	0.686	0.002	0.128	-0.005	-0.001	0.166	-0.185	-0.217	1						
Farming	0.328	1.086	0.111	-0.203	-0.068	-0.090	-0.269	-0.392	-0.460	-0.230	1					
Fishing	0.033	0.411	0.022	-0.085	0.025	-0.067	0.058	-0.103	-0.121	-0.060	-0.128	1				
End-users	0.284	1.044	-0.121	0.177	0.061	0.097	0.166	-0.079	0.219	0.339	-0.313	-0.116	1			
Trade	0.335	1.092	-0.015	-0.027	-0.009	0.016	0.017	0.031	0.255	-0.217	-0.168	0.073	-0.448	1		
Manufacturing	0.337	1.093	0.110	-0.113	-0.017	-0.091	-0.211	0.029	-0.455	-0.134	0.483	0.054	-0.449	-0.506	1	
City	0.232	0.976	-0.026	-0.016	0.016	0.046	0.080	-0.148	0.182	-0.050	0.026	-0.101	0.064	-0.008	-0.065	1

Note: Bold values are significant at the 0.05 level.