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Innovation and integration in the agri-food industry ☆

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ABSTRACT

We deal with the link between innovation and market structure using the empirical example of the Danish agri-food industry. Vertical integration may resolve hold-up problems and here we test for the importance of vertical integration and networks on innovation. We further examine the effects of network relationships on innovation behaviour. We use data from an extensive survey of 444 Danish firms over two years, 2000 and 2005 to estimate a bootstrapped zero-inflated Poisson regression model. The first and most significant result is that organization matters. Further we find that vertical integration as well as contractual arrangements are significant determinants for firms' innovation behaviour. The direction of integration is important as well. Also, economies of size seem to play an important role. Similarly, the export orientation of the firm is a significant determinant of innovation whereas the sector the firm is operating in is not significant for its innovation behaviour.

Introduction

Innovation is the commercialization of an innovative idea.[1] Firms will produce innovations when they have the ability to commercialize, to sell a product or service at a profit. The profitability of an innovation depends on the degree to which firms are able to capture the rents generated by their innovations (Arrow, 1958). Teece (1986, 2006) introduced the concept of an "appropriability regime" as the degree to which firms are able to capture the rents generated by their innovations. According to this notion, in a tight appropriability regime, firms can retain the profits they earn from their proprietary resources, while in a loose regime, these profits are subject to involuntary leakage or spillovers to other firms. The strength of the appropriability regime of an industry is related to patent strength, the value of first-mover advantage, and the ability to maintain the secrecy of an innovation (Teece, 1986; Levin et al., 1987; Gulati and Singh, 1998). These factors are also related to market structure. Especially with respect to firm integration and alliances the individual firm's concern about appropriation will vary depending on the industry in which the alliance occurs and the degree to which the appropriability regime in the industry is tight or loose. Hence, there should be a relationship between the appropriability regime of the industry and the prevailing form of integration, with more hierarchical structures expected in industries with weak appropriability regimes and more vertical structures expected in industries with strong appropriability regimes (Teece, 1986; Winter, 2006).

Different studies point to the relative low degree of appropriability in the food, beverages and tobacco industry compared to other industries in the EU. Most recently Peneder (2007) concludes that the appropriability conditions for the food industry are relatively weak and the cumulativeness of knowledge is rather low leading to an intermediate-to-low innovation intensity. However, compared to other European countries, Denmark shows in general a relatively tight appropriability regime (see e.g. Soegaard and Toft, 1998). The Danish economy has been rated as one of the most innovative in the world by agencies like the World Economic Forum (2007). Agriculture and food make up a significant portion of the Danish economy. This suggests the Danish food industry as an excellent case to empirically investigate the relative contribution of organizational characteristics to firms' innovation behaviour and leads us to the expectation that the food sector yields robust conclusions on our tests for innovative activity.

Organizational models or organizational choice is often what gives firms comparative advantage. In particular, it must be pointed out that "...the boundaries of the firm are an important strategic variable for innovating firms" (Teece, 1986, p. 304). What is not known is how the governance choice and the overall organization of the firm affect the process of innovation. We specifically examine in this paper the role of the choice of governance (spot market, vertical integration, contracts) on the level of innovation of agri-food firms.

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Institutions are also important in understanding the process of innovation. Institutions carry at least two meanings. First, institutions provide direction to research and development (R&D) and are expressed in the form of national research institutions. The analysis focuses on the economic returns to investment in R&D activities. This framework usually treats innovation as a black box. Second, institutions also refer to the 'rules of the game' (North, 1990). In this case emphasis is placed on property rights and the ability of firms to patent the new innovations. This creates the incentive for investment in research and development. Most of the research on innovation in the agriculture and food sector places greater emphasis on institutions than on the organization of firms (see e.g. Connor, 1981, or Weiss and Wittkopp, 2005). In this paper we examine the role of the organization of the agri-food firms on their level of innovation.

The study of innovation from an organizational view point has its roots in the work of Schumpeter (1943). There are two main conjectures that come out of this work. First, middle-size and large firms are central to innovation. Such firms have the capital base to be capable of conducting the research and bringing the new products or processes to the market. Second, how firms are organized is the key to understanding the innovation process (Coriat and Weinstein, 2002). Innovation is a process that is linked with different divisions within the firm or between firms – that makes the organization the critical variable. We focus on firm size as well as how the firm is organized in terms of vertical integration, contractual arrangements, relationship to foreign investment, ownership, market power, and other sector specific variables.

The purpose of this paper is to build models to test these conjectures using a unique set of data collected on the Danish food industry. The Danish food sector has been a world leader in organization and innovation (World Economic Forum, 2007). There exist numerous cooperatives and private firms that are vertically and horizontally integrated. This diversity in the type of organization makes the Danish food sector an ideal lab to examine the relationship between the organization of firms and the process of innovation.

The thrust of this paper and its main contribution to the literature is the empirical study of the role of the organization of the firm on innovation (see also Fagerberg et al., 2005). To our knowledge no such study exists particularly for the agri-food industry. The paper ties to the vast literature on the theory of the firm that dates back to Coase (1932) and his descendants. In this paper, we study empirically how the boundaries of the firm affect its ability to innovate. This seems to be important as innovation is one of the main vehicles for growth and profitability of firms. Hence, this study contributes to a better understanding of the link between firm organization and the dynamics of growth and profitability of firms and industries.

We develop an econometric model to test the effect of organizational variables along with other explanatory variables on our proxy for innovation: the number of new products. We apply a bootstrapped zero-inflated Poisson regression (ZIP) to estimate this model following the count data characteristics of the dependent variable. We find that organization matters and that vertical integration as well as contractual arrangements are significant determinants for firms' innovation behaviour. Also, economies of size and the export orientation of the firm are significant determinants of innovation. The sector the firm is operating in shows to be not significant for its innovation behaviour. The paper is organized as follows: Section "Theory" gives a theoretical review of the relevant literature followed by Section "Innovation in the agri-food industry" which describes the survey and the data set used. Section "Contribution" outlines the modelling and estimation procedures whereas Section "Methodology" reports and discusses the results. Section "Results" finally concludes.

Theory

Firms are involved in innovation activities if they are able, at least partially, to capture the benefits of their innovation. This ability to "appropriate" the fruits of the innovation process was recognized early by economic theorists and economic historians alike. Schumpeter (1943), was perhaps the first to recognize this, and to relate appropriability to market structure: Only if firms are large and have market power will be able to capture the generated rents.[2] Schumpeter is not clear as to the theoretical foundation of his claims, he touches upon the contractual problem (although he does not name it as such) and risk sharing, in that innovation investments are often indivisible and the innovating firm must be sturdy enough to bear the financial risk by itself (Winter, 2006, p. 1101).

The contract problem was dealt with more completely by Arrow (1958), where he introduces the information asymmetry problem, and what he calls, the "fundamental paradox": a buyer of innovation will not be willing to pay unless she knows what she buys – however, if all the secrets of the innovation are revealed the innovator abolishes any ability to capture rents from this unique product or process. This results in some fundamental market failure problem, hence, perfect competition becomes incapable to generate innovative activity because of the appropriability problem. While both Schumpeter and Arrow assign market power as the main determinant of the appropriability of innovation, Teece (1986, 2006) introduces the idea of complementary assets as a way to appropriate the benefits from innovation. Furthermore, it is very important the "appropriability regime ... which refers to the environmental factors, excluding firm and market structure, that govern an innovator's ability to capture the profits generated by an innovation. The most important dimensions of such a regime are the nature of the technology, and the efficacy of legal mechanisms of protection." (Teece, 1986, p. 287).

The market structure, in its classic industrial organization setting or in the more institutional conceptualization of an "appropriability regime" have been examined extensively. Similarly, the aspects of internal firm structure and their relation to innovation have been researched a great deal. However, very little theoretical and empirical work has been done on the relationship between vertical integration and innovation.

Vertical Integration

The link between innovation and vertical integration is not a new idea. Frankel (1955) attributes the slow rate of diffusion of innovations in the British industry in the late 1800s/early 1900s to the absence of vertical integration in the textile and iron firms. Similarly, Kindleberger (1964) argued that Japan and W. Germany had surpassed G. Britain because British manufacturing lacked vertically integrated firms. This, argues Kindleberger (1964), curbs incentives for firms to innovate since the benefits are scattered to other firms. Marx (1976) attributes the dominance of General motors in the electric locomotive industry to the fact that, contrary to its competitors, GM was integrated into electricity generation.

Armour and Teece (1980) posit three main reasons for the relationship between vertical integration and innovation. First,

[2] Interestingly enough, in his earlier work, in the book on "The Theory of Economic Development" (1912), Schumpeter argued that small outsider firms were more likely to be drivers of what he called "technological progress". He changed this view later in his "Business cycles" (1939) and much strongly in his "Capitalism, Socialism and Democracy" (1943, p. 106) ". ...What we have got to accept is that [the large-scale establishment or unit of control] has come to be the most powerful engine of ... progress and in particular of the long-run expansion of output not only in spite of, but to a considerable extent through, this strategy which looks so restrictive ... In this respect, perfect competition is not only impossible but inferior, and has no title to being set up as a model of ideal efficiency" (Quoted from Scherer, 1992, p. 1418).

transaction cost arguments: vertical integration circumvents the problem of holdup, hence a firm is more willing to undertake specific investment in innovation without worrying that it will be held up by the other party. Second, vertical integration can facilitate better the implementation of an innovation if this is required to take place downstream or upstream in the production process. Thirdly, vertical integration may facilitate better the alignment of objectives between the various stages of the innovation and development process. An empirical study of the chemical US industry confirms these theoretical predictions (Armour and Teece, 1980).

The effect of vertical integration on innovation may not be symmetric, affecting downstream and upstream firms in different directions. While the transaction cost arguments do not distinguish between upstream and down-stream integration, incomplete contract theory allows for the distinction between forward and backward integration. Acemoglu et al. (2007) use incomplete contract theory to show that vertical integration affects innovation decisions asymmetrically. What drives this model is the ex-ante allocation of property rights which determines the appropriability of the benefits from innovation. Specifically, it is shown that integration affects (downstream) producers and (upstream) suppliers in opposite directions: Backward vertical integration gives greater investment incentives to the producer (downstream), while forward vertical integration encourages supplier investment (upstream). Furthermore, backward integration discourages innovation for the upstream suppliers, while forward integration discourages innovation to downstream producers. This result is not aligned with the transaction cost theory which does not distinguish between forward and backward integration. The holdup argument would hold irrespective of who owns whom. Lambertini and Rossini (2008), also arrive to similar conclusions via a theoretical oligopoly model.

We hypothesize that innovation activity is expected to be related to vertical integration. Furthermore, it is likely that the effects to producers and suppliers are opposite for upstream and down-stream integration. We can then formulate Hypothesis 1 and the related Hypothesis 1a:

Hypothesis 1. Vertical integration is associated with higher levels of product innovation by firms.

Hypothesis 1a. The effects of forward and backward integration on innovation are a-symmetric.

The variables "ownership downstream" and "owned by upstream", "ownership upstream" and "owned by downstream" are used to test Hypotheses 1 and 1a.

Networks

Vertical integration in the form of direct ownership of another firm's assets was dealt with in the previous sub-section and in Hypothesis 1. Quasi integration, through contracts and other network arrangements, may also be key to innovation. We do not study here the formation of innovation networks, we rather examine the indirect effects of "quasi integration" on innovation activity.[3] Hanna and Walsh (2002) consider the increasing trend of inter-working among small firms to investigate if co-operation leads to innovation. Networks of small firms co-operate in certain activities, such as marketing, purchasing, R&D, training or manufacturing. The authors reveal that while networking is primarily a competitive response, it needs to evolve into a mechanism to enable small firms to develop innovative products and processes jointly. Like Hanna and Walsh many studies have investigated the determinants of product innovation in small firms, suggesting product, firm, market and innovation process factors are its key drivers of success. Variations across industries relating to the determinants of product innovation are often expected, but due to a lack of data this is still under-researched. De Jong and Vermeulen (2007) use cross-sectional data on small firms across different industries. Controlling for size and age differences the authors conclude that there exist major differences to the extent small firms use innovative practices, and their connection with new product introductions.

Formal contracts are written, legally binding agreements between two or more parties (Lyons and Metha, 1997). They are important instruments for the governance of exchange relations between economic actors because they represent promises or obligations to perform particular actions in the future (Mayer and Argyres, 2004). Transaction cost theory (Williamson, 1985) has contributed greatly to the study of inter-organizational exchange because it specifies in detail the nature and extent of risk in transactions and provides a theory and testable hypotheses of the factors that determine the design of contracts and the overall governance of transactions in such a way that risks are reduced and transactions costs are minimized (Williamson, 1985; Brousseau and Glachant, 2002). De Jong and Klein Woolthuis (2009) show that contracts have multiple functions: they are important to safeguard risks but are also used to co-ordinate alliance activities and show commitment; or to safeguard external contingencies. Hence, contractual relations perform an important function with respect to successful innovation alliances and activities (see also Ottaviano and Naghavia, 2006). We can the formulate the second hypothesis:

Hypothesis 2. Network links contribute to higher levels of product innovation.

We use the percentage of purchases and sales per firm covered by contracts: *percentage of raw materials covered by contracts; percentage of other inputs covered by contracts; percentage of sales to retailers covered by contracts; percentage of sales to wholesalers covered by contracts*. These network proxies are expected to be positively related to innovation.

Market power

The debate over the role of market power on innovation is as old as the economic theory of innovation, dating back to Schumpeter (1912, 1943). We deal here with the question of vertical market power, related to the concept of "countervailing power" (Galbraith, 1952), in other words, how does market power upstream or downstream affects a firm's innovation activity. In this study we were able to capture this in the retail and wholesale industries.

Von Ungern-Sternberg (1996) suggests that only if retail competition is strong, a concentration in this market will result in lower consumer prices. Chen (2004) points out that a monopolist faced by powerful retailers will tend to reduce product diversity. The negative impact on consumers' welfare may dominate the reduced price effect. Similarly Inderst and Shaffer (2007) show that horizontal mergers by retailers tend to reduce product variety. Further on, Inderst and Wey (2006) examine how downstream firms with market power may force suppliers into exclusive contracts and thus reduce incentives to innovate. Similarly Stefanadis (1997)

[3] Firms may form direct innovation networks to collaborate and manage the innovation activity, and very often these networks are ad hoc and project-oriented. "More and more of the work in America is project oriented, with a beginning, a middle and an end. Projects lend themselves to a blend of traditional employees, contract workers and consultants, who combine into teams, do a job and then usually break up, with most of the players looking for their next gig". "Flying Solo: High Tech Nomads Write New Program for Future of Work," The Wall Street Journal, August 19, 1996, p. A1. Robertson and Langlois (1994) conclude that neither organizational form (vertical integration versus network) is clearly better than the other, the choice depends on the nature and scope of the innovation and on the product life cycle. For a recent survey on "networks of innovators" see Powell and Grodal (2005).

shows that potential downstream foreclosure may force upstream manufacturers to withhold innovation activities. In a comprehensive study of the European retail sector, Dobson et al. (2001) point to the effect that large retailers may involve in a "loss leader" policy, where certain products are sold at prices below costs. Weiss and Wittkopp (2005) show that in Germany, market power by retailers has negative effects on food manufacturing firms' innovation activity (as measured by number of new products). Most of these studies look exclusively on downstream power (usually retailers) and do not examine upstream market power (input suppliers).

In summary, market power by downstream firms, will most likely curb incentives for innovation by upstream manufacturers. Similar effect we may expect from concentration of upstream suppliers. We can then formulate the third hypothesis:

Hypothesis 3. Market concentration upstream or downstream will reduce innovation activity. We capture this by two variables respectively: *number of firms selling 75% of all food-based inputs to the firm*; *number of firms buying 75% of all food-based sales from the firm*. A larger number of firms will indicate less market power, hence higher innovation activity.

Economies of size

One interpretation of the Schumpeterian hypothesis is that large firms will innovate more than small firms. The overall evidence supports this hypothesis. Scherer (1992) for example, found that 90% of the R&D in the USA was conducted by the 400 largest corporations. More careful measurement of innovation, however, casts doubt on the Schumpeterian argument. If one accounts for patents, for participation in research, etc. the evidence tilts towards that "there are no economies of scale with respect to firm size in the invention process" (Kamien and Schwartz, 1982, p. 3). More careful analyses show a u-shaped effect, where medium-sized firms tend to be more efficient innovators (Kamien and Schwartz, 1982; Mansfield, 1963). More recent studies also find evidence that small- and medium-size firms place a lot of effort on innovation (Rothwell, 1989; Traill and Grunert, 1997; Avermaete et al., 2004; Rothwell, 1989). The effect of firm size on innovation is therefore one relationship that needs to be investigated further:

Hypothesis 4. Innovation is expected to be higher for mid- and large-sized firms compared to small-sized firms.

Exports

Innovation and exports is of great interest to economic research. Some trade theorists (Krugman, 1979; Vernon, 1966) attribute exports to innovative behaviour of firms. At the firm level, however, the export orientation of innovative firms is ambiguous in the literature. Some find a positive relationship (e.g. Özçelik and Taymaz, 2004; Basile, 2001; Lachenmaier and Woessmann, 2006) while others find that non-innovative firms may export more (e.g. Wakelin, 1998), or that no significant differences exist per se (Bleaney and Wakelin, 2002; Geroski, 1990). Consequently, we formalize the following hypothesis:

Hypothesis 5. Export-oriented firms tend to innovate more and have a wider range of products.

To be able to empirically delineate the significance of these hypotheses we aim to control for firm size, the quality of the labour force (in terms of relative share of employees with higher level education), the marketing stage the firm is operating on (i.e. primary, wholesale, retail, processing or ingredients), and the sector the firm is operating in (i.e. feeding products, beef fruit and vegetables, pork, dairy, poultry or meat). Table 1 summarizes the different variables used for the empirical modelling and their measurement.

Innovation in the agri-food industry

Several studies have dealt with innovation in the food industry. In a comprehensive study of the European retail sector, Dobson et al. (2001) argue that increased power by retailers may decrease prices but also reduces product variety and innovation efforts by agri-food firms (Connor, 1981; and Roeder et al., 2000) study the effect on market structure on innovation of agri-food firms in the USA. A strong correlation between market concentration and innovation is found, although it is rather of a U-shape. Also a recent study by the Federal Trade Commission (FTC, 2003) suggests strong negative correlation between market concentration and innovation. The most relevant to our work is a recent study based on a survey of the German food industry by Weiss and Wittkopp (2005). They find that retail power decreases innovation by manufacturers, however, this negative impact is mitigated when manufacturers have market power. In their empirical model, Weiss and Wittkopp (2005) use "number of new products introduced" as an indicator of innovation by the firms. None of the studies we have reviewed has looked exclusively on the importance of vertical integration on innovation. Also, in our view, the fact that these studies measure innovation as "number of new products introduced," may be biased. We deal with both these issues in our paper.

Contribution

We aim to contribute to the literature in two distinct ways: First, we test for the importance of vertical integration for innovation. While there exist several studies on this linkage, to our knowledge, this is the first empirical study that deals with the agri-food industry. Secondly, it is the first study that quantitatively examines the effects of vertical integration on innovation for the agri-food industry in a comprehensive and analytical way.

Methodology

Data set

The data set used in the following analysis is based on a survey of 444 food industry firms in Denmark (see Baker, 2006). The survey questionnaire addressed several elements of the firms' organization, strategy and behaviour with respect to the year 2000 and 2005. The interview-based survey was conducted between November 2005 and March 2006 resulting in 131 valid responses (i.e. about 30% response rate and a total sample of 262 observations). Descriptive statistics for the data set employed in the models are shown in Table 2. For detailed explanations on the variables' definition and measurement see Table 1.

Modelling and estimation

To generate empirical evidence on the above stated hypotheses we formulate and estimate a bootstrapped zero-inflated poisson regression (ZIP). We consider the number of new products launched by the firm as an indicator for the level of innovation. Although, as discussed earlier, the number of new products as a proxy for innovation has several shortcomings, by the use of this measure we will be able to compare the results with other similar studies.

The number of products introduced by firm i at time $t - np_{it}$- is used as a proxy for the relative innovation behaviour of the firms in

Table 1
Variables and measurement.

Dependent variable	Measurement
Number of new products introduced *[np]*	Total number of new products introduced (as a new brand/brand name, under the firm's existing brand names, as retailers' own-label brands, unbranded products)
Independent variables	
Sales *[sales]*	Total sales in million DKK
Sales∗sales *[sales2]*	total sales in million DKK
Sales∗sales∗sales *[sales3]*	total sales in million DKK
Percentage of employees with university degree *[empluni]*	(employees with university degree/total number of employees) ∗ 100%
Percentage of sales originating from exports *[pcexp]*	(sales originating from exports/total sales in million DKK) ∗ 100%
Number of firms selling 75% of all food-based inputs to the firm *[nosell75]*	The total number of firms selling 75% or more of their products as food product related inputs to the firm
Number of firms buying 75% of all food-based sales from the firm *[nobuy75]*	The total number of firms buying 75% or more of their food inputs/products from the firm
Percentage of raw materials covered by contracts *[pcconraw]*	(purchase of raw materials covered by contracts/total purchase of raw materials) ∗ 100%
Percentage of other inputs covered by contracts *[pcconrawth]*	(purchase of other inputs covered by contracts/total purchase of other inputs) ∗ 100%
Percentage of sales to retailers covered by contracts *[pcconsret]*	(sales to retailers covered by contracts/total sales to retailers) ∗ 100%
Percentage of sales to wholesalers covered by contracts *[pcconsws]*	(sales to wholesalers covered by contracts/total sales to wholesalers) ∗ 100%
Ownership upstream *[ownup]*	1 – for firm holds shares in other firms up the marketing stage 0 – for firm holds no shares in other firms up the marketing stage
Ownership downstream *[owndown]*	1 – for firm holds shares in other firms down the marketing stage 0 – for firm holds no shares in other firms down the marketing stage
Owned by upstream *[ownbyup]*	1 – shares of the firm are held by other firms operating up the marketing stage 0 – no shares of the firm are held by other firms operating up the marketing stage
Owned by downstream *[ownbydown]*	1 – shares of the firm are held by other firms operating down the marketing stage 0 – no shares of the firm are held by other firms operating down the marketing stage
Stage of retailer *[stageret]*	1 – firm is a retailer, 0 – any other
Stage of wholesaler *[stagews]*	1 – firm is a wholesaler, 0 – any other
Sector of the fruit and vegetables industry *[secfrveg]*	1 – firm operates mainly in the fruit and vegetables industry, 0 – any other
Sector of the pork industry *[secpork]*	1 – firm operates mainly in the pork industry, 0 – any other
Sector of the dairy industry *[secdairy]*	1 – firm operates mainly in the dairy industry, 0 – any other

Table 2
Descriptive statistics.

Variable	Mean	Stdev	Min	Max
Number of new products introduced (*n*)	93.15	417.86	0	5000
Investment in R&D and/or product innovation (1 – yes, 0 – no)	0.65	0.48	0	1
Expenditure on R&D and product innovation (mill DKK)	14.51	50.85	0	535.05
Relative share of expenditures for R&D and product innovation (%)	4.49	7.78	0	45
Sales (mill DKK)	820.89	4684.65	1	46,400
Number of employees (*n*)	343.36	1993.84	1	20,000
Sales per employee (mill DKK)	4.16	10.67	0.01	133.33
Percentage of employees with university degree (%)	5.67	14.66	0	100
Foreign direct investment in the firm (1 – yes, 0 – no)	0.12	0.33	0	1
Percentage of sales originating from exports (%)	19.74	31.66	0	100
Percentage of raw materials covered by contracts (%)	48.68	44.12	0	100
Percentage of other inputs covered by contracts (%)	25.45	38.44	0	100
Percentage of sales to retailers covered by contracts (%)	29.59	40.78	0	100
Percentage of sales to wholesalers covered by contracts (%)	30.01	43.34	0	100
Ownership upstream (1 – yes, 0 – no)	0.05	0.22	0	1
Ownership downstream (1 – yes, 0 – no)	0.13	0.33	0	1
Owned by upstream (1 – yes, 0 – no)	0.03	0.17	0	1
Owned by downstream (1 – yes, 0 – no)	0.16	0.37	0	1
Stage of primary (1 – yes, 0 – no)	0.03	0.17	0	1
Stage of wholesaler (1 – yes, 0 – no)	0.29	0.46	0	1
Stage of retailer (1 – yes, 0 – no)	0.21	0.41	0	1
Stage of processor (1 – yes, 0 – no)	0.41	0.49	0	1
Stage of ingredients (1 – yes, 0 – no)	0.04	0.19	0	1
Sector of the feeding industry (1 – yes, 0 – no)	0.01	0.09	0	1
Sector of the beef industry (1 – yes, 0 – no)	0.04	0.19	0	1
Sector of the fruit and vegetables industry (1 – yes, 0 – no)	0.09	0.29	0	1
Sector of the pork industry (1 – yes, 0 – no)	0.02	0.15	0	1
Sector of the dairy industry (1 – yes, 0 – no)	0.18	0.38	0	1
Sector of the poultry industry (1 – yes, 0 – no)	0.05	0.21	0	1
Sector of the meat industry (1 – yes, 0 – no)	0.19	0.39	0	1
Sector unspecified (1 – yes, 0 – no)	0.43	0.49	0	1
Number of firms selling 75% of all food-based inputs to the firm (n)	2807.71	25166.88	1	260,000
Number of firms buying 75% of all food-based sales from the firm (n)	13.53	22.94	0	150

Note: All monetary values have been deflated to the base year 2000 using the general producer price index (*sources:* Danmark Statistic).

the sample. By definition this variable is censored by zero. This variable exhibits features similar to count data suggesting the use of a Poisson distribution to model its variation. The latter is widely used to describe models for count datasets, however, is often found to provide an inadequate fit due to the presence of many zeros in the data set. This is the case for the data set used in this study where more than 30% of the observations take the value zero for np_{it} implying no product innovated at all. To account for such excessive zeros in a discrete count variable, a zero-inflated Poisson distribution (ZIP) has been suggested in the literature (Lambert, 1992; Greene, 1994).

A ZIP distribution is a mixture of a standard Poisson distribution and a degenerated distribution at zero, with a mixing probability p. The dependent discrete count response variable np_{it} follows a zero-inflated Poisson distribution described by

$$\Pr(np_{it}|\mathbf{x}_i,\mu_i,\psi_i)=\begin{cases}\psi_i+(1-\psi_i)\exp(-\mu_i) & np_i=0\\ (1-\psi_i)\frac{\exp(-\mu_i)\mu_i^{np_i}}{np_i!} & np>0\end{cases} \quad (1)$$

Failure to account for the extra zeros may result in biased parameter estimates and misleading inferences. By applying a ZIP regression model based on (1) we modify the mean structure to increase the conditional variance and the probability of zero count. By adding the link functions

$$\ln(\mu_i)=\mathbf{x}_i'\boldsymbol{\beta} \quad (2)$$

and

$$\operatorname{logit}(\psi_i)=\ln\left(\frac{\psi_i}{1-\psi_i}\right)=\mathbf{x}_i'\gamma \quad (3)$$

where $\boldsymbol{\beta}$ and γ represent the coefficient vectors of the covariates $\mathbf{x}_i'$ serving as the log function of the mean μ_i and the logit function of the probability ψ_i instead. The joint log-likelihood function for the ZIP regression is given by

$$\begin{aligned}L(\boldsymbol{\beta},\gamma|np,\mathbf{x})=&\sum_{i=1}^{n}1(y_i=0)\ln\{\exp(\mathbf{x}_i'\gamma)+\exp[-\exp(\mathbf{x}_i'\boldsymbol{\beta})]\}\\&+\sum_{i=1}^{n}[1-1(y_i=0)][y_i\mathbf{x}_i'\gamma-\exp(\mathbf{x}_i'\boldsymbol{\beta})]\\&-\sum_{i=1}^{n}\ln[1+\exp(\mathbf{x}_i'\gamma)] \quad (4)\end{aligned}$$

where $1(y_i=0)$ is a function taking the value 1 as $y_i=0$ and 0 otherwise. Eq. (4) is estimated by a maximum likelihood procedure. The final estimation model specification is given by

$$\begin{aligned}np_{it}=&(\exp(\beta_0+\beta_1 sales_{it}+\beta_2 sales_{it}^2+\beta_3 sales_{it}^3+\beta_4 pcexp_{it}\\&+\beta_5 empluni_{it}+\beta_6 nosell75_{it}+\beta_7 nobuy75_{it}\\&+\beta_8 pcconraw_{it}+\beta_9 pcconrawth_{it}+\beta_{10} pcconsret_{it}\\&+\beta_{11} pccons ws_{it}+\beta_{12} ownup_{it}+\beta_{13} owndown_{it}\\&+\beta_{14} ownbyup_{it}+\beta_{15} ownbydown_{it}+\beta_{16} stageret_{it}\\&+\beta_{17} stagews_{it}+\beta_{18}\sec frveg_{it}+\beta_{19}\sec pork_{it}+\beta_{20}\\&\times\sec diary_{it}+u_1))/((1+\exp(\gamma_0+\gamma_1 sales_{it}^2+\gamma_2 sales_{it}^3\\&+\gamma_3 nosell75_{it}+\gamma_4 nobuy75_{it}+\gamma_5 pcconraw_{it}\\&+\gamma_6 pcconrawth_{it}+\gamma_7 pcconsret_{it}+\gamma_8 ownup_{it}+\gamma_9\\&\times\sec frveg_{it}+\gamma_{10}\sec pork_{it}+\gamma_{11}\sec diary_{it}+u_2)) \quad (5)\end{aligned}$$

where i denotes the observation, $t=2000, 2005$; and the variables are based on the definitions shown in Table 1. Assuming that the over dispersion of zeros does not arise from heterogeneity in the data set but from the nature of the firms' innovation decisions, we have to test for whether there is a regime splitting mechanism at work or not (Greene, 1994). Hence, we use the test statistic developed by Vuong (1989) for non-nested models based on the assumption that the alternative distribution (here: $f_2(np_i|\mathbf{x_i})$ as the standard Poisson model) can be specified and $m_i=\log(f_1(np_i|\mathbf{x_i})/f_2(np_i|\mathbf{x_i}))$ with f_1 as the null hypothesis distribution described by (1)

$$v=\sqrt{n\left[\frac{1}{n}\sum_{i=1}^{n}m_i\right]}\Bigg/\sqrt{\frac{1}{n}\sum_{i=1}^{n}(m_i-\bar{m})^2} \quad (6)$$

testing for $E[m_i]$ equals zero, omitting t for simplicity and using the fact that v has a limiting standard normal distribution. To test further for small-sample bias we investigate the robustness of our estimates obtained by (5) by applying a simple stochastic re-sampling procedure based on bootstrapping techniques (see Efron and Tibshirani, 1993). This seems to be necessary as our data set consists of a (rather) limited number of observations and time units. If we suppose that $\hat{\omega}$ is an estimator of the parameter vector ω including all parameters $\boldsymbol{\beta},\gamma$ obtained by estimating (5) based on our original observations X_i, then we are able to approximate the statistical properties of $\hat{\omega}$ by studying a sample of $C=1000$ bootstrap estimators $\hat{\omega}(c)_k,\ c=1,\ldots,C$. These are obtained by re-sampling – with replacement – from $X$and re-computing $\hat{\omega}$ by using each generated sample. The final sampling characteristics of our vector of parameters is obtained from

$$\hat{\boldsymbol{\omega}}=[\hat{\omega}_{(1)k},\ldots,\hat{\omega}_{(1000)k}] \quad (7)$$

As is extensively discussed by Horowitz (2001) or Efron and Tibshirani (1993), the bias of the bootstrap as an estimator of $\hat{\omega}_k$, $B_{\hat{\omega}}=\tilde{\omega}_k-\hat{\omega}_k$, is itself a feasible estimator of the bias of the asymptotic estimator of the true population parameter ω_k.[4] This holds also for the standard deviation of the bootstrapped empirical distribution providing a natural estimator of the standard error for each initial parameter estimate. By using a bias corrected bootstrap we aim to reduce the likely small-sample bias in the initial estimates. To examine the validity of the final model specification we finally test for a joint as well as a group wise insignificance of the parameters in (5) by a generalized likelihood ratio testing procedure. Further diagnosis tests were conducted to test for possible serial correlation (following Wooldridge, 2002) as well as heteroscedasticity (following White, 1980). Both were rejected.

Results

Table 3 summarizes the results for the estimated model. The diagnostic tests conducted indicate no severe serial correlation, no rejection of the normality hypothesis with respect to the residuals, and a rejection of the hypothesis of model misspecification at the 1% level of significance for all models: the Vuong test statistic rejects a standard Poisson model specification in favor of the ZIP specification. The model shows a satisfactory overall model significance, given the modest sample size and the use of survey data (see adjusted McFadden's R^2 values and the Maximum Likelihood R^2s). These conclusions are backed up by the bootstrapped bias-corrected standard errors. The conducted linear hypotheses tests with respect to the significance of the explanatory variables' composition finally indicate the relevance of size related effects, employee based factors, integration relevant effects (i.e. contractual and ownership based), as well as retail and wholesale stage related factors (see linear hypotheses tests performed).

The model verifies the basic hypothesis (Hypothesis 1) put forward in this paper: Vertical integration is a significant determinant of innovation. Specifically, the organization variables related to

[4] Hence the bias-corrected estimator of ω_k can be computed by $\hat{\omega}_k-B_{\hat{\omega}}=2\hat{\omega}-\tilde{\omega}$.

Table 3
Bootstrapped ZIP regression estimates ($n = 132$).

Independents	Dependent: number of products innovated		
	Coefficient[1]	*Z*-value	Bias-corrected standard error 95% confidence interval
Zip model – Poisson			
Sales	1.28e−03***	7.63	[1.37e−04; 1.88e−04]
Sales∗sales	3.30e−07***	3.04	[8.78e−08; 1.16e−07]
Sales∗sales∗sales	−7.64e−12***	−3.37	[1.83e−12; 2.41e−12]
Pct of sales from exports	0.032***	21.90	[9.37e−04; 1.72e−03]
Pct of employees with university education	−7.51e−03**	−3.87	[1.43e−03; 2.64e−03]
Number of firms selling 75% of all food-based inputs to the firm	5.25e−03***	5.31	[6.36e−04; 2.66e−03]
Number of firms buying 75% of all food-based sales from the firm	1.02e−05***	7.29	[1.03e−06; 1.77e−06]
Pct of purchases of raw materials covered by contracts	8.67e−03***	10.38	[6.18e−04; 1.07e−03]
Pct of purchases of other inputs covered by contracts	6.43e−03***	7.12	[7.16e−04; 9.98e−04]
Pct of sales to retailers covered by contracts	8.67e−03***	7.03	[9.13e−04; 1.46–03]
Pct of sales to wholesalers covered by contracts	2.55e−04*	0.23	[8.54e−04; 1.20e−03]
Ownership upstream	0.621***	2.66	[0.01; 0.35]
Ownership downstream	0.964***	11.23	[0.06; 0.10]
Owned by upstream	2.014***	12.69	[0.32; 0.65]
Owned by downstream	0.705***	12.44	[0.04; 0.07]
Stage of the wholesaler	2.122***	24.44	[0.06; 0.12]
Stage of the retailer	0.539**	2.14	[0.17; 2.57]
Sector of the fruit and vegetables industry	0.638***	4.82	[0.09; 0.18]
Sector of the pork industry	−5.601***	−12.12	[2.07; 3.41]
Sector of the dairy industry	−0.795***	−9.36	[0.07; 0.11]
Constant	1.679***	16.14	[0.08; 0.14]
Inflation model – logit			
Sales∗sales	4.89e−06**	1.89	[1.38–06; 1.01e−05]
Sales∗sales∗sales	1.05e−10**	1.89	[2.97e−ll; 5.77e−10]
Number of firms selling 75% of all food-based inputs to the firm	0.05***	2.63	[0.07; 0.04]
Number of firms buying 75% of all food-based sales from the firm	0.01***	2.74	[0.009; 0.011]
Pct of purchases of raw materials covered by contracts	0.03***	3.06	[6.35e−03; 0.06]
Pct of purchases of other inputs covered by contracts	0.02*	1.61	[0.008; 0.016]
Pct of sales to retailers covered by contracts	0.04***	3.01	[6.57e−03; 0.04]
Ownership upstream	4.08***	2.40	[1.56; 4.54]
Sector of the fruit and vegetables industry	4.23***	2.84	[3.44; 5.83]
Sector of the dairy industry	−3.13***	−2.80	[0.52; 4.37]
Constant	−0.958***	−4.74	[0.18; 0.23]
logLL	−1408.84	AIC	21.679
Zero observations/non-zero observations	41/91	Adj. McFadden 's R^2	0.829
Vuong test of zip versus standard Poisson	2.34*** (standard rejected)	Maximum Likelihood R^2	0.733
Wooldridge testLR $chi^2(1)$ (H_o: no serial correlation)	−1254.85 (not rejected)	LR $chi^2(20)$	13916.71***
White's test chf(llO) (H_o: homoscedastic errors)	131.99 (not rejected)	Bootstrap Replications	1000
Linear hypotheses tests on model specification ($chi^2(x)$) – zip specification			
H_o: size related variables have no significant effect ($chi^2(2)$)	916.75*** (rejected)		
H_o: contract related variables have no significant effect ($chi^2(4)$)	186.52*** (rejected)		
H_o: ownership related variables have no significant effect ($chi^2(4)$)	377.26*** (rejected)		
H_o: retail stage related variables have no significant effect ($chi^2(2)$)	54.89*** (rejected)		
H_o: wholesale stage related variables have no significant effect ($chi^2(2)$)	621.42*** (rejected)		

* −10%-level of significance.
** −5%-level of significance.
*** −1%-level of significance.

vertical integration and contractual characteristics are significant and with the expected sign (see Table 3). We discuss each hypothesis below.

- **Hypothesis 1.** Vertical integration. The coefficients for both ownership upstream and downstream variables are positive and significant. Firms that indicated that they have some degree of vertical integration tend to innovate more.
- **Hypothesis 1a.** The direction of integration does not matter in general, both upstream and down-stream integration tend to increase product innovation. Although the effects are in the same direction, down-stream integration is more important than upstream. *Ownership Downstream* shows a larger coefficient than *Ownership Upstream* (0.964 versus 0.621), and *Owned by Upstream* shows a larger effect than *Owned by Downstream* (2.014 versus 0.705). A firm that owns a downstream firm, or it is owned by an upstream firm is more likely to innovate than a firm which owns a downstream firm or is owned by an upstream firm. It appears that the benefits of innovation are more likely to be captured downstream. Therefore, in a pair of vertically integrated firms when majority ownership is controlled by the upstream partner, both the upstream and the downstream firms are more likely to innovate. The incentive to innovate is weaker if the majority owner is the downstream partner. Although we do not find asymmetric (opposite signs) effects of integration on innovation (as Acemoglu et al., 2007), we find different intensities of innovation depending on the direction of integration. Although we can not accept Hypothesis 1a per se, the results are an indication that the direction of vertical integration is important on the decision to innovate, and calls for further research on the issue.
- **Hypothesis 2.** Networks (proxied by contractual relations) play also an important role in innovation activity. The three contract variables used (purchase contracts for raw materials and other inputs; sales contracts to retailers) were significant and with positive sign.

- **Hypothesis 3.** Market power (proxied by the number of firms selling to- or buying from- the firm more than 75% of the firm's inputs or final product respectively) showed to be significant. The larger the number of firms that the firm deals with, the larger the number of new products the firm tends to introduce. It indicates that network linkages may have positive effects on the introduction of new products by firms, since the number of new products introduced increases with the number of firms that the firm buys from, or sells to. One possible interpretation of the result is this: Firms who sell to a large number of firms may have to differentiate their product in order to cater to each customer's needs. Therefore, large number of firms downstream may increase the demand for a large number of products. On the other hand, if a firm tends to introduce a large number (and variety) of new products it may need a large variety of inputs, hence the need to procure from large number of input suppliers (large number of firms upstream).
- **Hypothesis 4.** Economies of size. Size appears significant in the model. Both the squared and cubic terms are positive and significant, indicating that product innovation has strong economies of size. Larger firms will supply a wider range of products. This is a weak indication of a U-shaped effect, indicating that mid-sized firms may be more likely to innovate as found elsewhere in the literature (Kamien and Schwartz, 1982; Mansfield, 1963; Rothwell, 1989; Traill and Grunert, 1997; Avermaete et al., 2004).
- **Hypothesis 5.** Export orientation. Firms with export orientation tend to innovate more as the variable pct sales from exports is significant and positive. Our results tend to agree with that of trade theorist's (Krugman, 1979; Vernon, 1966) and empirical results from other industries (Özçelik and Taymaz, 2004; Basile, 2001; Lachenmaier and Woessmann, 2006).

We introduced several sectoral and stage dummies to control for sectoral and stage effects on innovation. The variable Sector of the Fruits and Vegetables Industry has a positive sign, whereas the variables for the pork and dairy sectors show negative signs. Recall that the dependent variable in our model is the number of new products, and it indicates that it is more difficult for pork and dairy firms to introduce new products compared to fruits and vegetables producing firms. The stage dummies, indicate that both wholesaler and retailer firms are more likely to introduce new products.

Conclusions

We have used a unique data set based on an extensive survey of more that 400 Danish agri-food firms and analyzed what determines innovation activities of these firms. Specifically, we were interested to see the effects of organization, vertical integration, contractual and other network agreements. We also tested for the effects of other variables, such as size, and stage in the chain. We used as a dependent variable the number of new products introduced and applied a ZIP model to estimate the impacts of the hypothesized variables. The model performed reasonably well and the results were fairly consistent for the main hypotheses.

The first and most significant result is that organization matters. Vertical integration as well as contractual arrangements were significant for both models. Both upstream and downstream ownership (vertical integration) were significant, however, ownership by an upstream firm had a larger effect on innovation than ownership by downstream firms. Also, it was more important to own a firm than to be owned by one. Contractual arrangements had positive effects on innovation for both models. The degree of network linkages upstream or downstream is significant has positive effects for a firm's innovation activity. Economies of size seem to play an important role and it was significant in the empirical model. Similarly, the export orientation of the firm was a significant determinant of innovation. Whereas the sector was not significant, the stage in the chain was important: wholesalers and retailers tend to have a larger number of new products. In general, the results of this research were satisfactory. We confirmed the hypotheses that organization, size and market power are important determinants of innovation.

Finally, additional analysis on the effects of organizational characteristics on a firm's innovation behaviour is warranted. Such analysis should predominantly focus on the implications of the size of a firm for its organizational disposition and eventually for its innovation behaviour over time.

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