Innovation, Integration and Product Proliferation - Empirical Evidence for the Agri-Food Industry

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Abstract

While mergers, both horizontal and vertical, have been shaping the landscape of the agri-food industry in Europe, the implications of the changing market structure on the level of innovation has not been studied yet. In this paper we deal with the link between innovation and market structure using the empirical example of the Danish agri-food industry. The purpose of this paper is two-fold. First we test for the importance of vertical integration on innovation. While there exist several studies on this linkage, to our knowledge, this is the first that deals with the agri-food industry. Secondly, we examine both product proliferation and innovation. To our knowledge, there are no other similar studies that examine both aspects using the same data set. We follow the hypothesis put forward by Armour and Teece (1980) that vertical integration enhances technological innovation, mainly because vertical integration may resolve hold-up problems. Our paper is related also to recent work by Weiss and Witkopp (2005) on the German food industry, although their work is mostly related to the role of the retail sector. We are able to examine both innovation (measured as investment on R&D) as well as product proliferation (measured as number of new products). We also examine the effects of network relationships and the importance of countervailing power.
We use data from an extensive survey of 444 Danish firms over two years, 2000 and 2005 to estimate two different models: a bootstrapped zero-inflated Poisson regression and a robust Heckman sample selection model. The results verify the hypotheses formulated for both models with various degrees of significance.

Keywords: *Innovation, Vertical Integration, Product Proliferation, Agribusiness*

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1. INTRODUCTION

A major source of economic growth is innovation. Economic competitiveness is linked to the ability of firms to innovate. With much of the economy hanging on the ability of firms to innovation both industry and governments have placed the understanding of the process innovation very central to their policy. In the agri-food industry in particular, market forces and to a great extend the globalization process, have been driving the industry towards more innovations in order to address market needs and face increased competition. At the same time, however, the level of research and development expenditures (R&D) in the food industry is rather low compared to total manufacturing (EU, 2007). In this paper we examine some of the determinants of innovation in the agri-food industry.

Organization gives pre-eminence to the firm and the different types of organization. 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.

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' as described by institutional theorists (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. In this paper we examine the role of the organization of the agri-food firms on their level of innovation.

Very often innovations lead to new product development. This is not always true, however, especially in the case of process innovation (as opposed to product innovation). In this case, one needs to examine both the level of innovation, as well as the introduction of new products by firms. We examine both issues separately by testing two distinct models, one using R&D activity, and another using new product introduction, as two distinct measures of innovation for agri-food firms.

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, larger firms are central to innovation. Large 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 and market power, as well as how the firm is organized in terms of vertical integration, contractual arrangements, market power, relationship to foreign investment, ownership 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. 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 two models to test the effect of organizational variables along with other explanatory variables on two proxies for innovation, respectively: the number of new products and secondly the R&D expenditure. We apply appropriate econometric techniques in each case: a bootstrapped zero inflated Poisson regression (ZIP) following the count data characteristics of the first dependent variable and a robust Heckman sample selection model to account for the truncated second dependent variable. The paper is organized as follows: section 2 gives a theoretical review of the relevant literature and section 3 describes the survey and the data set used. Section 4 outlines the modelling and estimation procedures used, section 5 reports and discusses the results and section 6 finally concludes.

2. THEORY

For many years, the discussion on innovation was dominated by the Schumpeterian argument of the importance of monopoly power as a prerequisite for investment on innovation (Schumpeter, 1942). However, the virtues and benefits of monopoly and competition are not the only factors determining innovation. It is now well-known that innovation is among other things a result of management and organization decisions (Teece, 1989; Traill and Grunert, 1995). It is useful to distinguish between two types of innovation (Grunert, et. al., 1995; Tirole, 1988)[1]: a. *Product innovation* refers to the development of new products and services; and b. *Process innovation* which reduces production costs or enables the production of new products.

The distinction between product and process innovation is not always clear and very often creates confusion in empirical research. We can approximate the level of innovation activity of a firm either by measuring the output of, or the input to innovation. As an output proxy the number of new products introduced each year is usually used. As input to innovation the level of R&D expenditures is usually used. Thus, product proliferation and innovation are two closely linked activities of firms. It can be argued that innovation is a pre-requisite (sufficient but not necessary) for product proliferation: "*Technological change, […] can expand the product space by making additional dimensions possible, by adding more classifications on existing discrete axes, or by extending the range of continuous axes. Thus, technological change can be said to be a sufficient condition for product proliferation. It is not a necessary condition, however, because some physical differentiation (e.g. changes in package size) can occur with a static technology*" (Connor, 1981, p. 609).

There are several reasons why product proliferation may be a different process and firm strategy than innovation. First, not all new products are a result of "innovation". There may be simple product differentiation that has little to do with innovation, research and development activities. Hence, the number of new products may not be directly related to the amount and efforts invested. Large and long-term amounts may result into a small number of new products, whereas

[1] Another very important category is "organizational innovation', we do not deal with this here (See Damanpour, 1991 for a review)

firms pursuing aggressive product differentiation strategies may not be innovators at all. Secondly, even if we assume that all new products are a result of innovative activities by the firm, they only capture the success stories. There is a lot of uncertainty involved in the outcomes of innovation and not all innovation results in new products. Hence, firms that invest in innovation and did not launch new products in the time period covered by the study will appear as not innovating at all. Thirdly, the R&D investment may simply be on pure process innovations aimed at reducing costs of producing existing products. Hence, although there is investment in innovation it will not materialize into new products.

For the above reasons, new products as a proxy for innovation can create two types of empirical fallacies: **Type A Falacy:** Measuring "new products" the researcher may *over-estimate* innovation since part of it is mere "*product proliferation*" or simply product of past investments[2]. In Figure 1, if the researcher observes "new product" it is not possible to differentiate between nodes D and F. The firm may be an innovator (nodes A-D) or non-innovator (nodes B-F). **Type B Falacy:** Investment on innovation may not result into new products, hence, "new products" may actually *under-estimate* innovation[3]. In Figure 1, this corresponds to not being able to differentiate between nodes A-C and B-E.

<FIGURE 1 HERE>

It is difficult to distinguish the two types of fallacies empirically. Also, as our focus is on the effects of market structure, we need to distinguish between the two. Therefore, we chose to use both measures: new products, and innovation expenditures (as percentage of total firm's expenditures)

[2] Also, given the lags between investment in research and results, new products during the sampling period may be a result of innovation in previous periods.
[3] Furthermore, given that some research and innovation activities take long to produce results, we may not observe any new products during the sampling period, while large investments on innovation are under-taken .

and estimate two separate models with different control variables and estimation techniques. The methodology is outlined in section 3.

The incentives for innovation (and/or product proliferation) may vary between manufacturers and retailers. While manufacturers view product variety as a booster for their demand, retailers may fear additional inventory costs and therefore may prefer fewer products. Therefore the type of the agrifood firm and its place in the agri-food chain are very important variables.

Our focus and main hypothesis is that market structure determines both innovation and product proliferation. More specifically, we firstly hypothesize that vertical integration, the existence of networks and retail market power determine innovation and proliferation of products. Secondly, we hypothesize that economies of size are a determinant of innovation and product proliferation. Thirdly, we hypothesize that as we move down the chain firms will tend to introduce more new products, while firms upstream will tend to innovate more. Below we discuss the theoretical and conceptual foundation of these hypotheses.

Vertical integration

The link between innovation and vertical integration is well known. 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.

Economides (1997) shows that integrated monopolists will provide higher quality and wider variety of products. In a study of the music industry Allain and Woelbroek (2004) find that vertical integration increases product variety. The main reason is that vertical integration reduces double marginalization and the fixed costs of innovation are better internalized by the vertically integrated entity than a chain of separated monopolies. They also show that competition at the downstream market increases product variety upstream.

Innovation is a very special process. Both the resources required to producing it and its outcome are not directly measurable and hence not easily contractible. Resources such as knowledge - particularly organizational knowledge – and the product of innovation and know-how are not easily transferable. As a result, markets are not always the appropriate form for the governance of innovation transactions. Instead firms involved in such activities rely on a variety of hierarchical (vertical integration) or hybrid organizational forms such as networks, strategic alliances, cooperatives, etc.

The appropriability of the benefits from innovation activities is key for firms to invest in R&D. Hence property rights, patents, and overall transaction cost arguments are crucial. Armour and Teece (1980) study systematically the hypothesis that vertical integration enhances technological innovation, mainly because vertical integration may resolve hold-up problems (Williamson, 1985). Also, because a clearer definition of goals existst since communication between R&D and other departments is better facilitated in vertically integrated firms (Armour and Teece, 1980). The results from an econometric study on the US petroleum industry support their main hypothesis. Using a different (ex ante) chain of logic, Balakrishnan and Wernerfeldt (1986) argue that the risk of technological obsolescence will curb the firms' incentives to vertically integrate. Our first hypothesis then can be stated as:

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

Networks

Quasi integration, through contracts and other network arrangements, is key to innovation[4]. One reason is economies of scale and scope which can be captured through inter-firm arrangements (Teece, 1996, p. 198). 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.[5]

Hypothesis 2: Similar to vertical integration, network relations contribute to higher levels of innovation and product proliferation. Hence contractual relations (as a proxy of networks) are expected to be positively related to innovation and product proliferation.

Countervailing power

The debate is old and started with Galbraith's (1952) hypothesis on "countervailing power" [6] asserting that firms will develop economic power on one side of the market in order to "countervail" the market power exercised by firms on the other side of the market. Galbraith uses examples such as trade unions (developed to countervail power of employers), and cooperatives (to countervail power of buyers of farm products). Also, the retail chains were created, according to Galbraith, in order to countervail the power exercised by suppliers and hence to reduce prices paid to wholesalers and processors. The welfare implications of the countervailing power hypothesis are however somewhat controversial, since a review of the literature suggests that the results depend on market structure. There are two effects of countervailing power with opposite effects on consumer welfare: a potential consumer price decrease and a reduction on product variety. Von Ungern-

[4] "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.

[5] For a recent survey on "networks of innovators" see Powell and Grodal (2005)

[6] "...private economic power is held in check by the countervailing power of those who are subject to it. The first begets the second. The long trend towards concentration of individual enterprise in the hands of a relatively few firms has brought into existence not only strong sellers, as economists have supposed, but also strong buyers as they fail to see. The two develop together, not in precise step but in such manner that there can be no doubt that the one is in response to the other." (Galbraith, 1952)

Sternberg (1994) 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 countervailing power by 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 (2002) examine how downstream firms with market power may force suppliers into exclusive contracts and thus reduce incentives to innovate. Similarly Stefanadis (1997), 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. This raises concerns by manufacturers who may refrain from innovation activities fearing that consumers may perceive their products as being of lower quality if they are sold at too low prices. Using a different (ex ante) chain of logic, Balakrishnan and Wernerfeldt (1986) argue that the risk of technological obsolescence will curb the firms' incentives to vertically integrate. Weiss and Wittcopp (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). We can expect the effects to be similar:

Hypothesis 3: Countervailing power, upstream or downstream, will decrease innovation and product proliferation.

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 (1991) 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, 1985, p.3). More careful analyses show a u-shaped effect, where medium-sized firms tend to be more efficient innovators (Kamien and Schwartz, 1985; Manfield, 1963). More recent studies also find evidence that small- and medium-size firms place a lot of effort on innovation (Rothwell, 1989; Grunert, et. al. 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 and product proliferation are expected to be higher for mid-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. Oszek and Taymaz (2004); Basile (2001); Lachenmaier and Wosmann, 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..

Innovation and product proliferation 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 (2000) argue that increased power by retailers may decrease prices but also reduces product variety and innovation efforts by agri-food firms. Connor (1981; and Röder, 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, 2000) 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. Although in the right direction, this indicator may be measuring product proliferation rather than product innovation. As we indicate above, this may lead to a certain bias.

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

Hence, we aim to contribute to the literature in three 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 that deals with the agri-food industry. Secondly, by using two different empirical models with two different dependent variables (number of new products introduced and investment on innovation) we examine both product proliferation and innovation. To our knowledge, there are no other studies that examine both aspects using the same data set. Finally, it is the first study that examines the effects of vertical integration on innovation and product proliferation for the agri-food industry in a comprehensive and analytical way.

3. METHODOLOGY

Data

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 1.

There has been substantial consolidation in the Danish food sector in the period 1995-2000 (Baker, 2003). The reduction in number of food processing firms has been much faster in Denmark than in other parts of Europe. Similarly the reduction in wholesale firms in the food industry has reduced faster in Denmark than most other EU countries. In terms of concentration the Danish food sector is similar to other parts of Europe. Denmark has CR5 of about 56% while the CR4 in the US is about 27% at the national level. However, when buying power is considered the Danish effective CR is around 70% which is representative for the rest of the EU. One strong trend that has occurred in the Danish food marketing chains is the increase in the share of the wholesale market controlled by non-specialized stores. This trend is apparent in most EU countries, but Denmark shows the largest increase. In contrast the US has shown a strong increase in all types of food retailing outlets. 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 which leads us to the expectation that the food sector yields robust conclusions on our tests for innovative activity.

<TABLE 1 HERE>

Modelling and Estimation

To generate empirical evidence on the above stated hypotheses we formulate and estimate two different regression models depending on the choice of the dependent variable: Model I. Number of new products (np_{it}); Model II: Investments on innovation as percentage of total sales ($rexpinno_{it}$). They are presented analytically below.

Model I: Number of Products Innovated (np_{it}) - A Bootstrapped Zero Inflated Poisson Regression (ZIP)

We first 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 as well as to examine the determinants of product proliferation.

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 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

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

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

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

and

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

where $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ 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

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

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

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

where i denotes the observation, t = 2000, 2005; *pcexp* refers to the percentage of sales originating from exports, *empluni* is the percentage of employees with university degree, *nosell75* as the number of firms selling 75% of all food-based inputs to the firm, *nobuy75* as the number of firms buying 75% of all food-based sales from the firm, *pcconraw* refers to percentage of raw materials covered by contracts, *pcconrawth* as the percentage of other inputs covered by contracts, *pcconsret* as the percentage of sales to retailers covered by contracts, *pcconsws* as percentage of sales to wholesalers covered by contracts, *ownup* denotes if the firm has ownership in firms up the chain, *owndown* denotes if the firm has ownership in firms down the chain, *ownbyup* refers to if the firm is owned by firms up the chain, *ownbydown* refers to if the firm is owned by firms down the chain, *stageret* measures the effect of the firm belonging to the retail stage, *stagews* measures the effect of the firm belonging to the wholesale stage, and *secfrveg*, *secpork*, *secdiary* denotes if the firm produces fruit and vegetables, pork, or diary products.

Asssuming 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 $m_i = \log\left(f_1(np_i|\mathbf{x_i}) / f_2(np_i|\mathbf{x_i})\right)$ with f_1 as the null hypothesis distribution described by [1]

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

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 $\hat{\boldsymbol{\omega}}$ is an estimator of the parameter vector $\boldsymbol{\omega}$ including all parameters $\boldsymbol{\beta}, \boldsymbol{\gamma}$ obtained by estimating [5] based on our original observations X_i, then we are able to approximate the statistical properties of $\hat{\boldsymbol{\omega}}$ by studying a sample of C = 1000 bootstrap estimators $\hat{\boldsymbol{\omega}}(c)_k, c = 1,...,C$. These are obtained by re-sampling – with replacement – from X and re-computing $\hat{\boldsymbol{\omega}}$ by using each generated sample. The final sampling characteristics of our vector of parameters is obtained from

$$\hat{\boldsymbol{\omega}} = \left[\hat{\boldsymbol{\omega}}_{(1)k},...,\hat{\boldsymbol{\omega}}_{(1000)k}\right] \qquad [7]$$

As is extensively discussed by Horowitz (2001) or Efron and Tibshirani (1993), the bias of the bootstrap as an estimator of $\hat{\boldsymbol{\omega}}_k$, $B_{\hat{\omega}} = \tilde{\boldsymbol{\omega}}_k - \hat{\boldsymbol{\omega}}_k$, is itself a feasible estimator of the bias of the asymptotic estimator of the true population parameter $\boldsymbol{\omega}_k$.[7] 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.

Model II: Investments on innovation as percentage of total sales ($rexpinno_{it}$) - A Robust Heckman Sample Selection Model

As suggested earlier, new products may over- or under-estimate innovation activities by firms. Agri-food firms' innovation behaviour can be further approximated by the decision to invest in innovation at all (i.e. the participation decision) as well as the relative amount of expenses devoted to innovation in a particular period of time (i.e. the expenditure decision). Accordingly, only a subsample of firms are able to report innovation expenditures. It is likely that the sectoral and organizational characteristics of the firms engaged in innovation are different from those not

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

engaged in innovation. Unobservable characteristics affecting the decision to invest in innovation are correlated with the unobservable characteristics affecting innovation expenditure. Selectivity bias would be the case, therefore, if we were to draw inferences about the determinants of innovation expenditures for all agri-food firms based on the observed expenditures of the subset which is engaged in innovation. Heckman's sample selection model copes with such a selection problem by assuming that the firms make two decisions with regard to investing in innovation, each of which is determined by a different set of explanatory variables (see Heckman, 1979). Hence, it is based on two latent dependent variables models, where the innovation expenditure decision is described as

$$rexpinno^{*}_{it} = \boldsymbol{\beta}'\mathbf{x_{it}} + \mathbf{u}_1 \qquad [8]$$

with *rexpinno* as the amount of total expenditures spend on innovation (as % of total sales) and the innovation investment decision as

$$inno^{*}_{it} = \boldsymbol{\gamma}'\mathbf{z_{it}} + \mathbf{u}_2 \qquad [9]$$

where *inno* is a binary variable taking the value 1 as the firm decides to invest in innovation, and the value 0 otherwise. Where **x** and **z** are vectors of regressors, possibly containing common components including intercepts, and the errors u_1 and u_2 are conditional on **x** and **y** and are jointly bivariate normally distributed with zero mean. The model in [8] is only observable if $inno^{*}_{it} > 0$ and the observed dependent variable is

$$\begin{aligned} rexpinno_{it} &= rexpinno^{*}_{it} && \text{if } inno^{*}_{it} > 0 \\ rexpinno_{it} &= \text{missing value} && \text{if } inno^{*}_{it} = 0 \end{aligned} \qquad [10]$$

and hence, **z** is observable if $rexpinno_{it}$ is a missing value and **x** is observable if $rexpinno_{it}$ is. Asymptotically efficient estimators of [8] and [9] are obtained by maximizing the log-likelihood function

$$L(\boldsymbol{\beta},\boldsymbol{\gamma},\rho,\sigma)=\sum_{i=1}^{n}\left\{\begin{array}{l}D_i\ln\left[h(Y_i|\mathbf{x}_i,\mathbf{z}_i,\boldsymbol{\beta},\boldsymbol{\gamma},\rho,\sigma)\right]+D_i\ln\left[\Phi(\boldsymbol{\gamma}'\mathbf{z}_i)\right]\\+(1+D_i)\ln\left[1-\Phi(\boldsymbol{\gamma}'\mathbf{z}_i)\right]\end{array}\right\} \quad [11]$$

where D_i is defined as a dummy variable taking the value 0 if $rexpinno_{it}$ is a missing value and the value 1 if not, Φ is the cumulative distribution function of the standard normal distribution, σ as the standard error of $\mathbf{u}_1$, ρ as the correlation between u_1 and u_2, h denotes the conditional density of $rexpinno_{it}$ given $inno_{it}>0$, $\mathbf{x}$ and $\mathbf{z}$ (see also Bierens, 2002). The final estimation model specification is given by

$$\begin{aligned}
rexpinno^*_{it} &= \beta_0+\beta_1 pc\exp_{it}+\beta_2 empluni_{it}+\beta_3 ownup_{it}+\beta_4 owndown_{it}+\beta_5 ownbyup_{it}+\beta_6 ownbydown_{it}\\
&+\beta_7 stagews_{it}*owndown_{it}+\beta_8 stagews_{it}*ownup_{it}+\beta_9 pcconraw_{it}*ownup_{it}\\
&+\beta_{10} pcconraw_{it}*owndown_{it}+\beta_{11} pcconrawth_{it}*ownup_{it}+\beta_{12} pcconrawth_{it}*owndown_{it}\\
&+\beta_{13} pcconsret_{it}*ownup_{it}+\beta_{14} pcconsret_{it}*owndown_{it}+\beta_{15} pcconsret_{it}*ownbyup_{it}\\
&+\beta_{16} pcconsret_{it}*ownbydown_{it}+\beta_{17} pcconsws_{it}*ownup_{it}+\beta_{18} pcconsws_{it}*owndown_{it}+u_{1it}\\
inno^*_{it} &= \gamma_0+\gamma_1 sales_{it}+\gamma_2 sales^2_{it}+\gamma_3 sales^3_{it}+\gamma_4 empl_{it}+\gamma_5 stageproc_{it}+\gamma_6 stagews_{it}\\
&+\gamma_7 stageingr_{it}+u_{2it}
\end{aligned} \quad [12]$$

where i denotes the observation, t = 2000, 2005; *stageproc* measures the effect of the firm belonging to the processing stage, *stageingr* measures the effect of the firm belonging to the ingredients stage, and the rest of the variables are defined as outlined above. We further use cross term variables to explain the variation in the level of innovation expenditures by taking into account the cross effects between different aspects of organizational integration (i.e. contractual and ownership). To address the likely problem of small sample bias as well as heteroscedasticity because of survey data we estimate the robust covariance matrix using the Huber-White sandwich estimator (see Huber, 1967 and White, 1980). The latter provides consistent estimates of the covariance matrix for parameter estimates even when the fitted parametric model fails to hold because of misspecification or violation of the error related assumptions.[8] Puhani (2000) showed that the full-information ML estimation of the Heckman selection model is preferable in the case where collinearity problems are absent. Despite several cross variables terms used in the model, the auxiliary regressions performed showed no severe collinearity in the explanatory variables. To examine the validity of the final model specification we test for a group wise insignificance of the parameters in [5] by a generalized likelihood ratio testing procedure. Finally a Wald test of independence is used to obtain evidence on the accuracy of the specification based on dependent equations, as well as various diagnostic tests were conducted to test for possible serial correlation (following Wooldridge, 2002) as well as heteroscedasticity (following White, 1980).

4. RESULTS

Tables 2 to 3 summarize the results for the estimated models. 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 (model 1), and the Wald test statistic rejects the specification based on independent probit and tobit models in favor of the chosen Heckman selection specification (model 2). All models estimated show a satisfactory overall model significance, given the modest sample size and the use of survey data (see adjusted McFadden's R^2 values, the Maximum Likelihood R^2s, and the McKelvey/Zavoina's R^2 values). These conclusions are backed up by the bootstrapped bias-corrected standard errors as well as the robust estimation technique applied for the Heckman selection specification which confirm the robustness of the various estimates. The conducted linear

[8] Here the estimate is calculated as the product of three matrices: the matrix formed by taking the outer product of the observation-level likelihood/pseudolikelihood score vectors is used as the middle of these matrices, and this matrix is in turn pre- and postmultiplied by the usual model-based variance matrix (see in detail e.g. Greene, 2000).

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 for all three specifications (see linear hypotheses tests performed).

Both models verify the basic hypothesis (Hypothesis 1) put forward in this paper: Vertical integration is a significant determinant of innovation. Specifically, in both models, the organization variables related to vertical integration and contractual characteristics are significant and with the expected sign (see tables 2 and 3). We discuss each hypothesis below.

<TABLE 2>

<TABLE 3>

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. The direction of integration does not matter in general, both up-stream and down-stream integration tend to increase innovation and product proliferation. However, downstream integration is more important than upstream. In Model I, Ownership Downstream shows a larger coefficient than Ownership Upstream (0.964 versus 0.621). Whereas Owned by Upstream shows a larger effect (2.014 versus 0.705). In Model II, Ownership Downstream and Owned by Downstream are both more significant than their Upstream counterparts. It is more important that the innovating firm owns another firm upstream or downstream, than if another firm has shares in it. Ownership of another firm (both upstream and downstream) is significant and by a large order of magnitude more important than Owned By (Owned by upstream is not significant).

Hypothesis 2. Networks (proxied by contracts) play also an important role in innovation activity. In Model I the three contract variables used (purchase contracts for raw materials and other inputs; sales contracts to retailers) were significant and with positive sign. In Model II, the effect of contractual relations are combined with vertical ownership: buying contracts of raw materials or other inputs combined with vertical integration (upstream or downstream). All but two coefficients were significant and positive.

Hypothesis 3. Countervailing power.

This is captured by the number of firms selling to- or buying from- the firm more than 75% of the firm's inputs or final product respectively. The larger the number of firms the lower the degree of countervailing power. These variables (one for upstream and one for downstream) was significant only in the first equation (number of new products). 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, thus, that countervailing power may have detrimental 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 should point out, however, that the number of firms is a weak proxy of market power, since concentration is very important. Since we do not exclusively use concentration ratio, or other measures of market power, we should view this result with caution. 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 both equations in Model I. Both the squared and cubic terms are positive and significant, indicating that product proliferation has strong economies of size. Larger firms will supply a wider range of products. In Model II, however, size is only significant in the selection equation, with the squared term negative and significant. None of the size variables were significant in the Logit equation. 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, 1985; Manfield, 1963; Rothwell, 1989; Grunert, et. al. 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 in both models. Our results tends to agree with that of trade theorist's (Krugman, 1979; Vernon, 1966), and empirical results from other industries (Oszek and Taymaz (2004); Basile (2001); Lachenmaier and Wosmann, 2006).

Hypothesis 6. Sectoral and stage variables. We introduced several sectoral and stage dummies to control for sectoral and stage effects on innovation. The results are not consistent between the two models. In Model I, the Fruits and vegetables Sector has a positive sign, whereas pork and dairy are negative. Recall that the dependent variable in this model is *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. None of the sectoral dummies were significant in Model II. This is perhaps due to the fact that all firms in the sample are from the same industry (agri-food) indicating that they are all affected by similar overall market structure and industry regulation and they all have access and "draw" from the same pool of technological and scientific knowledge (Kamien and Schwartz 1984).

The stage dummies, however, indicate that both wholesaler and retailer firms are more likely to introduce new products (Model I). This is an interesting result. Here, we most likely measure product proliferation, rather than innovation. The results in Model II indicate that firms in the processing, wholesale and ingredients stages of the chain, will tend to invest more in innovation, as expected.

5. 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 market power, size, and stage in the chain. We used two different measures of innovation and applied two different models. First, we used as a dependent variable the number of new products introduced and used a ZIP model to estimate the impacts of the hypothesized variables. Second, we used investment on R&D as a proxy for innovation input and used a Heckman sample selection model. Both models performed reasonably well and although there were slight differences in the variables that turned out to be significant between the two models, 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. Other hypotheses concerned the effect of market power. The degree of countervailing market power upstream or downstream is significant and has detrimental effects for a firm's innovation activity. Economies of size seem to play an important role and it was significant in both equations. Similarly, the export orientation of the firm was a significant determinant of innovation. Whereas the sector was not significant in any of the equations, the stage in the chain was important. Wholesalers and retailers tend to have a larger number of new products (Model I), whereas manufacturing firms tend to invest more in R&D (Model II). In general, the results of this research were satisfactory. We confirmed the hypotheses that organization, size and market power are important determinants of innovation.

REFERENCES

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Table 1 – 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)[1]	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	46400
number of employees (n)	343.36	1993.84	1	20000
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	260000
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).

Table 2 Bootstrapped ZIP Regression Estimates

(n = 132)	Dependent: Number of Products Innovated		
Independents	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^2	3.30e-07***	3.04	[8.78e-08; 1.16e-07]
sales^3	-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^2	4.89e-06**	1.89	[1.38-06;1.01e-05]
sales^3	1.05e-10**	1.89	[2.97e-11; 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	4.33***	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 vs. standard Poisson	*2.34*** (standard rejected)*	*Maximum Likelihood R^2*	*0.733*
Wooldridge test LR $chi^2(1)$ (H_0: no serial correlation)	*-1254.85 (not rejected)*	*LR $chi^2(20)$*	*13916.71****
White's test $chi^2(110)$ (H_0: homoscedastic errors)	*131.99 (not rejected)*	*Bootstrap Replications*	*1000*

linear hypotheses tests on model specification ($chi^2(x)$) - zip specification

H_0: size related variables have no significant effect ($chi^2(2)$)	*916.75*** (rejected)*
H_0: contract related variables have no significant effect ($chi^2(4)$)	*186.52*** (rejected)*
H_0: ownership related variables have no significant effect ($chi^2(4)$)	*377.26*** (rejected)*
H_0: retail stage related variables have no significant effect ($chi^2(2)$)	*54.89*** (rejected)*
H_0: wholesale stage related variables have no significant effect ($chi^2(2)$)	*621.42*** (rejected)*

1: * - 10%-, ** - 5%-, *** - 1%-level of significance.

Table 3 Robust Heckman Selection Estimates

(n = 166) Independents	coefficient[1]	robust z-value	coefficients 95% confidence interval
stage 1 – selection equation	**Dependent 1: Decision to Invest in R&D and/or Product Innovation**		
sales	2.63e-03*	1.69	[-4.24e-04; 5.69e-03]
$sales^2$	-4.04e-06**	-2.33	[-7.44e-06; -6.42e-07]
$sales^3$	8.34e-10**	1.87	[-4.01e-11; 1.71e-09]
number of employees	4.51e-03**	2.36	[7.70e-04; 8.23e-03]
stage of the processor	1.36***	4.40	[0.75; 1.97]
stage of the wholesaler	1.05***	3.41	[0.44; 1.65]
stage of the ingredients	7.25***	15.15	[6.31; 8.19]
constant	-1.15***	-4.56	[-1.65; -0.66]
stage 2 – level equation	**Dependent 2: Relative Expenditure on R&D and Product Innovation**		
pct of sales from exports	0.08**	2.14	[6.78e-03; 0.16]
pct of employees with university education	0.11**	2.44	[0.02; 0.21]
ownership upstream	190.53***	31.11	[129.56; 251.50]]
ownership downstream	663.48***	4.73	[388.77; 938.19]
owned by upstream	2.11	0.51	[-6.01; 10.23]
owned by downstream	3.76***	3.46	[1.63; 5.88]
stage of the wholesaler x ownership downstream	306.32***	4.62	[176.47; 436.17]
stage of the wholesaler x owned by upstream	6.92***	3.02	[2.43; 11.40]
pct of purchases of raw materials covered by contracts x ownership upstream	36.17***	6.02	[24.39; 47.94]
pct of purchases of raw materials covered by contracts x ownership downstream	6.64***	4.72	[3.88; 9.39]
pct of purchases of other inputs covered by contracts x ownership upstream	21.09***	6.03	[14.23; 27.95]
pct of purchases of other inputs covered by contracts x ownership downstream	-3.17e-03	-0.21	[-0.03; 0.03]
pct of sales to retailers covered by contracts x ownership upstream	170.01***	6.02	[114.69; 225.33]
pct of sales to retailers covered by contracts x ownership downstream	0.60***	5.07	[0.37; 0.84]
pct of sales to wholesalers covered by contracts x ownership downstream	0.67***	4.73	[0.39; 0.95]
pct of sales to wholesalers covered by contracts x ownership upstream	110.77***	6.10	[74.71; 146.83]
pct of sales to retailers covered by contracts x owned by upstream	0.09***	2.65	[0.02; 0.16]
pct of sales to wholesalers covered by contracts x owned by upstream	-0.04	-0.79	[-0.12; 0.05]
constant	5.48***	2.99	[1.88; 9.08]
score variable ρ	-0.49*	-1.86	[-1.25; 0.27]
lnσ	1.77***	9.23	[1.39; 2.15]
ρ	-0.45***	-4.08	[-0.85; 0.26]
Σ	5.90***	5.22	[4.50; 8.61]
nonselection hazard (= inverse Mill's ratio) λ	*-2.67***	*-2.57*	*[-6.69; 1.34]*
log pseudo-LL	*-389.034*		
censored / uncensored observations	*70 / 96*		
Wald test of indep. equ. (ρ = 0), $chi^2(1)$	*11.59** (rejected)*		
McKelvey/Zavoina's R^2	*0.769 (selection equation)*		*0.959 (level equation)*
Maximum Likelihood R^2	*0.993 (full model)*		
AIC	*5.024*		
Wooldridge test LR $chi^2(1)$ (H_0: no serial correlation)	*-1432.14 (not rejected)*		
White's test $chi^2(37)$ (H_0: homoscedastic errors)	*34.68 (not rejected)*		

1: * - 10%-, ** - 5%-, *** - 1%-level of significance.

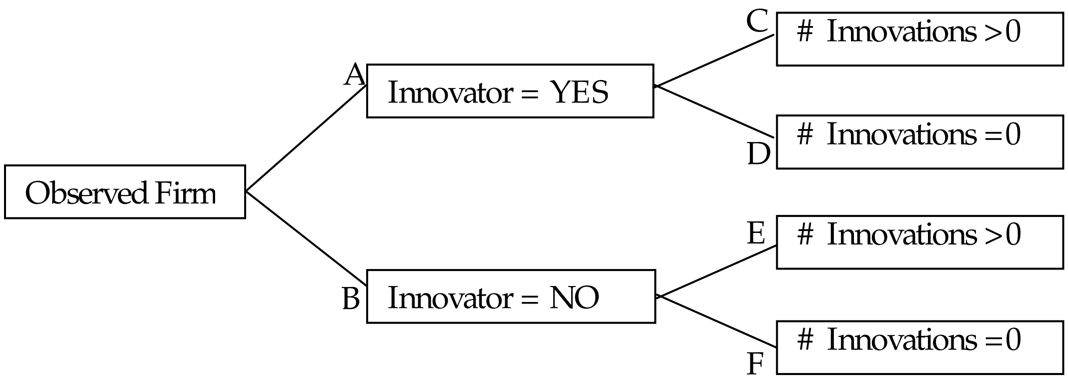

Figure 1. Biases on Measuring Innovation