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User–producer interaction as a driver of innovation: costs and advantages in an open innovation model

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While drawing on theories of distributed innovation and search, we conjecture that because a lot of important knowledge can only be obtained through the use of a product, the use of customer knowledge is beneficial for firms' innovative performance. However, the use of customer knowledge also has an important downside as customers may often be conservative (for many good reasons), forcing producer firms to search for new solutions along established paths, while shying away from truly new and promising opportunities. In this paper these two forces are reconciled through an argument stating that there is an inverse U-shaped relationship between the intensity of the use of customer knowledge and innovative performance. We hypothesize that the negative effect at high levels of intensity of the use of customer knowledge is offset by firms' broader search strategies in terms of the breadth of external search among other sources of innovation: If firms search more broadly among several sources of innovation, they are much more likely to enjoy the benefits of customer knowledge, while avoiding important negative aspects. Overall, we find empirical support for these conjectures.

IN AN IMPORTANT AND INFLUENTIAL paper, Bengt-Åke Lundvall (1988) pointed to the importance of interactive learning in general — and user–producer interaction in particular — in the context of successful product innovation. Against this background, Lundvall argued that user–producer interaction has several important characteristics, including that it is durable over time and that such interaction is often more efficient over a short geographical distance, especially when user needs are complex and ever-changing. Indeed, both before and after Lundvall's paper, the importance of firms' attention to users' needs and knowledge has been confirmed in numerous empirical studies (for instance, Rothwell *et al*., 1974; Von Hippel, 1976; Andersen *et al*., 1981; Gardiner and Rothwell, 1985; Lundvall, 1988; Neale and Corkindale, 1998; Lilien *et al*., 2002; Jeppesen and Frederiksen, 2006).

Although the literature has paid considerably less attention to the issue, there can also be negative sides of user–producer interaction in the context of innovation. Lundvall (1988) himself noted that user–producer interaction can lead to 'unsatisfactory' innovations — among other things, because of inertia in user–producer relationships. Similarly, in a very influential book, Clayton Christensen (1997) later argued that when incumbent firms fail as innovators, it is because existing customers keep them captive and make them follow established technological trajectories, even when truly new and better opportunities emerge.

However, little research has been conducted attempting to analyze the conditions under which the use of customers' knowledge may be beneficial or potentially harmful.[1] In this paper, this issue is addressed and it is argued that the potentially damaging effects of relying strongly on customers in the innovation process are offset by firms' other efforts in terms of technological exploration. In particular,

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we suggest that having a high search breadth in terms of other external knowledge sources (Laursen and Salter, 2006; Grimpe and Sofka, 2009; Leiponen and Helfat, 2010) can offset the negative effect of relying strongly on customers. We also examine Lundvall's suggestion that local (national) collaboration with customers matters particularly for product innovation.

Our ideas are tested on the Danish CIS4 data — involving a sample of 3,418 manufacturing and service firms — with the percentage of sales of innovative products as the dependent variable. We find that using customers as a source of innovation is significantly associated with higher levels of innovative sales. However, emphasizing customers beyond a certain point produces a negative effect on innovative sales. It is also found that this relationship is positively moderated by the search breadth in terms of other external knowledge sources. These results hold both for products only new to the firm (more incremental innovation) and for innovations new to the firm's market (more radical innovation). We find support for Lundvall's idea that local (national) collaboration with customers concerning innovation matters more for product innovation than international collaboration with customers, but only in the case of more incremental innovation. In the case of more radical innovation, both national and international collaboration with customers for innovation seem to matter for innovative sales.

Previous research on user–producer interaction

As noted in the introduction, customers' (and other users') knowledge has very often proven to be critical for innovation success. It has been pointed out that successful innovation requires attention to users' needs (Rothwell *et al.*, 1974), that users' knowledge is central to the development of established firms' new products (e.g. Urban and Von Hippel, 1988; Neale and Corkindale, 1998; Lilien *et al*., 2002; Bogers *et al*., 2010), and that the central content of innovations in some cases comes from users (Von Hippel, 1976; Franke and Shah, 2003; Jeppesen and Frederiksen ,2006). In this context, Lundvall (1988) and others (prominent contributions include: Linder, 1961; Rosenberg, 1982; Von Hippel, 1994) have highlighted the importance of communication and joint learning between customers and other users on the one hand, and the producers of innovation on the other hand, in producing successful innovation.

The fact that national upstream–downstream interaction matters for innovation in many industries has found support in the empirical literature on international trade (see e.g. Fagerberg, 1995; Laursen and Meliciani, 2000). At the firm level, surprisingly few large-scale quantitative studies examining the role of user–producer relationships in the context of innovation exist (there is a very substantial literature, supplying case-study evidence). However, for instance, Meeus *et al*. (2001) find that interactive learning with customers is positively associated with the complexity and structuring of innovative activities and with moderate scores of the cross-product term of the complexity of innovative activities and the strength of internal knowledge resources.

Interactive learning with customers seems positively affected by higher technological dynamics. Weterings and Boschma (2009) show that for a sample of Dutch software firms, spatial proximity facilitates face-to-face interactions, but does not strengthen the effect of face-to-face interactions on innovative performance. Moreover, regular interactions and collaboration with customers appear to increase the likelihood that software firms will bring new products to the market, but do not improve the size of firm's innovation output. Also at the micro level, Beise-Zee and Rammer (2006) examined the relationship between user-induced innovation and exports for both manufacturing and service firms. When their innovation variable is replaced by a variable reflecting whether or not the firm in question had user-induced innovation, this variable is also significant in explaining export activities of firms. Concerning customers (national or international) specifically, Laursen and Salter (2006) show that the two most important external sources of innovation among UK firms were 'suppliers' and 'clients or customers'; 66% of the sample of UK manufacturing firms indicated that they had used clients or customers as a source of knowledge or information for innovation, and 16% indicated that they had used clients or customers as a source of knowledge or information for innovation to a high degree.

Hypotheses

Lundvall (1988, 1992b) argued that successful product innovation will most often involve social interaction between producers and users (often customers) of an innovation. Producer firms can get information about customers/users' needs (e.g. in the form of being able to observe problems and bottlenecks experienced by user firms). On the other side, customers/users may obtain information about technological possibilities from producers, and about the

competence a producer firm might have with respect to solving customers' problems. According to the distributed innovation literature, there are two overall reasons why users/customers may contribute to the innovation process. First, in many cases they are the principal beneficiaries of the innovation (Von Hippel, 1988). Second, customers often posses 'sticky' knowledge (i.e. knowledge that is difficult and hence costly to transfer) (Von Hippel, 1998).

Stickiness may be caused by various attributes of knowledge itself, such as the way it is encoded (in the form of tacit or codified knowledge), or it may be caused by the attributes of the agents seeking or providing knowledge (in particular, their cognitive capacities and motivations). Thus, the customer may possess knowledge about the performance and operating characteristics of a machine that may turn out to be an essential input in the modification of the machine. However, such knowledge is likely to be dispersed among a number of employees of the customer firm (who may lack motivation to share it), and is likely to have a considerable 'tacit' component. Marshalling this knowledge so that it can be used as input in the innovative process requires direct interaction between the customer/user and the producer (Rosenberg, 1982: 124). Seen from the point of view of the producer-firm, the stickiness of knowledge implies that it will be advantageous to interact with customers (and users more broadly) as such collaboration allows for access to knowledge that the focal firm would be unable to produce in-house.

While there are benefits from using customers' knowledge in the production of innovations, there may also be downsides, when firms become too reliant on current customers' knowledge. Although collaborating with customers is a form of boundary-spanning search in the sense of spanning organizational borders, it may not be helpful in spanning other border such as technological ones (Rosenkopf and Nerkar, 2001; Rothaermel and Alexandre, 2009). Indeed, Christensen (1997) has forcefully argued that current customers prefer solutions that they are familiar with. Accordingly, existing customers force incumbent firms to follow established technological trajectories — also in situations when truly new opportunities emerge — and as a result, incumbent firms are often unable to innovate. Earlier on, Lundvall (1988) also noted that user–producer interaction can lead to 'unsatisfactory' innovations, because of inertia in user–producer relationships and due to the existence of 'conservative' (and sometimes incompetent) users. One way of reconciling these viewpoints would be to say that customer knowledge in a central ingredient in introducing product innovation, but that a very strong reliance may carry penalties to the extent of producing negative returns. In sum, the arguments presented above leads us to posit:

For the producer-firm, the stickiness of knowledge implies that it will be advantageous to interact with customers as such collaboration allows for access to knowledge that the focal firm would be unable to produce in-house

H1. The uses of customer knowledge in the innovation process is curvilinearly (taking an inverted U-shape) related to innovative performance.

Laursen and Salter (2006) define external search breadth as the number of different external search channels that a firm draws upon in its innovative activities. They focus on search channels such as suppliers, users and universities that firms use in their search for innovative opportunities. Evolutionary economists highlight the role of search in helping organizations to find sources of variety, allowing them to create new combinations of technologies and knowledge (Nelson and Winter, 1982). Such variety provides opportunities for firms to choose among different technological paths (Metcalfe, 1994). Laursen and Salter (2006) hypothesize that external search breadth influences innovative performance, assuming that the product development process is itself a form of problem-solving activity and the associated search processes involve investments in building and sustaining links with users, suppliers and a wide range of different institutions inside the innovation system.

Following Scott and Brown (1999), Brown and Duguid (2000) and Laursen and Salter (2006), each of these channels can be seen as a separate search space, encompassing different institutional norms, habits and rules; often requiring different organizational practices in order to render the search processes effective within the particular knowledge domain. Accordingly, building links with different sources of knowledge is costly as firms need to understand and respect these different institutional norms, habits and rules. Moreover, when firms build too many external links, they are likely to experience attention-allocation problems and hence not benefit from the available external knowledge (Laursen and Salter, 2006). This argumentation leads us to posit:

H2. External search breadth is curvilinearly (taking an inverted U-shape) related to innovative performance.

A central tenet of this paper is that the reliance on customers may lead firms to become less innovative because customers may become conservative over time and cease to be a valuable source of knowledge for the

focal firm. However, if the focal firm is open to other search channels than customers in the form of external search breadth, this problem could to some extent be alleviated. A broad external search breadth signifies that a focal firm gets knowledge from a wide set of external sources. Accordingly, a firm that searches broadly gets a variety of ideas from external sources, not only from customers. This attention to other sources of knowledge than customers creates the preconditions for a complementary relationship that may also help firms avoid situations where existing customers keep them captive and make them follow established technological trajectories. The complementarity may emerge because a focal firm can gain knowledge of technological opportunities by working with, for instance, an external technology supplier or a university, while at the same time utilizing the 'sticky' knowledge possessed by the customer. Working with other sources of knowledge is also a route to keeping managers less focused on a central source of knowledge (such as customers), and hence to avoid the myopia of learning (Levinthal and March, 1993) from working with customers. These arguments lead us to conjecture:

H3. Above the top point of the inversely U-shaped relationship between the use of customer knowledge in the innovation process and innovative performance, a high-level external search breadth will reduce the negative effect of very high uses of customer knowledge.

In the majority of cases, innovations require the parallel orchestration of different skills and knowledge (Brown and Eisenhardt, 1995). These skills and knowledge may typically not be readily available inside the firm, and may be very costly to develop (Rosenberg, 1982). Given that pure market exchange will not allow close enough coupling of the interdependent research and development process, a possible solution to these problems is to collaborate with users of products in order to facilitate information exchange, mutual learning and other interdependent activities. Such collaboration can facilitate complex coordination beyond what the price system can accomplish, while avoiding the dysfunctional properties sometimes associated with hierarchy (Lundvall, 1988; Von Hippel, 1988; Teece, 1992; Singh, 1997). As pointed out by Lundvall and Von Hippel, given the mutual interest between user and producers of innovations and the frequently observed need for exchanging information between producers and customers during the product development period (a period during which problems and solutions emerge constantly), direct collaboration is often fruitful when it comes to introducing product innovations.

Certainly, when users and producers induce an understanding of reciprocal needs, interactive learning can emerge as a result. Such learning involves the establishment of technical codes, tacit and specific to the partners. Social learning may also limit opportunism by creating similar behavioral codes, and hence create a fertile environment for innovation (Lundvall, 1992b). National collaboration with customers for innovation may be important due the possible significance of geographical and cultural distance. Lundvall (1988) argues that low distances in these dimensions can be important due to the need to communicate between users and producers in flexible and complex ways when co-creating innovations. Such communication is much more costly over longer distances. Lundvall also suggests that:

> a common cultural background might be important in order to establish tacit codes of conduct and to facilitate the decoding of the complex messages exchanged. (1988: 355)

Nevertheless, internationally dispersed sources of knowledge may enhance the technological opportunity set of innovators (Cantwell and Janne, 1999), thus resulting in more innovations (even when communication is much more costly), especially in the small-country case (as in our case), where the local set of knowledge in terms of its variety and size may be limited. In sum:

H4. Collaboration with national and international customers has a positive association with innovative performance.

As pointed out in the introduction to this paper, Lundvall argued that user–producer is durable over time and that such interaction is often more efficient over a short geographical distance, especially when user needs are complex and ever-changing. It is widely recognized that face-to-face contact is required for exchanging and co-creating knowledge (Lawson and Lorenz, 1999) and that such personal contact is facilitated by geographical proximity (Rosenthal and Strange, 2003; Storper and Venables, 2004). In sum:

H5. Collaboration with national customers will affect to innovative performance stronger than international collaboration with customers.

Data and variables

The data set

The data for the analysis is drawn from the Danish innovation survey (CIS4). The CIS4 survey was implemented in 2005 and is based on the core Eurostat Community Innovation Survey (CIS) of innovation (DCSRRP, 2006b). The method and types of questions used in innovation surveys are described in the Organization for Economic Co-operation and Development's Oslo Manual (OECD, 1997). CIS data have been used in over 100 recent academic articles. Recent prominent contributions using CIS data

include Cassiman and Veugelers (2006) and Leiponen and Helfat (2010). CIS surveys of innovation are often described as 'subject-oriented' because they ask individual firms directly whether they were able to produce an innovation. The interpretability, reliability and validity of the survey were established by extensive piloting and pre-testing before implementation within different European countries and across firms from a variety of industrial sectors, including services, construction and manufacturing.

The CIS questionnaire draws from a long tradition of research on innovation, including the Yale survey and the SPRU innovation database (for examples, see Levin *et al*., 1987; Pavitt *et al*., 1987; Cohen and Levinthal, 1990; Klevorick *et al*., 1995). CIS data provides a useful complement to the traditional measures of innovation output, such as patent statistics (Kaiser, 2002; Leiponen and Helfat, 2010). The questionnaire asks firms to indicate whether the firm has been able to achieve a product innovation. Product innovation is defined as:

> A product innovation is the introduction to the market of new or significantly improved goods or services, for instance through improved components, subsystems or improved software and user-friendliness. The innovation has to be new to the firm, but needs not be new to the industry or market. It is not relevant whether or not the innovation was developed by the focal firm or by other firms. (DCSRRP, 2006b: 4, the author's translation)

Firms are then asked to state what share of their sales can be ascribed to different types of innovation, such as innovations new to their markets. Alongside these performance questions, there are a number of questions about the sources of knowledge for innovation, the effects of innovation, intellectual property strategies, expenditures on R&D, and other innovative activities.

The Danish innovation survey is 12 pages long and includes a page of definitions. The sample of respondents was created by the Danish Centre for Studies in Research and Research Policy (DCSRRP) at the University of Aarhus. It was sent to the firm's official representative for filling in information on the firm's activities, such as surveys for calculating the gross domestic product and R&D expenditures. It was normally completed by the managing director, the chief financial officer, chief marketing officer or by the R&D manager of the firm. The implementation of the survey was administered by the DCSRRP and to guide respondents a help service was provided (DCSRRP, 2006b).

The survey was sent to approximately 4,400 business units in Denmark in May 2005. The responses were voluntary and respondents were promised confidentiality. The sample includes all main industries of the Danish economy, excluding public bodies, and hotels and restaurants. After three reminders, the survey received a response rate of 50.4% (DCSRRP, 2006b: 14). Based on responses to the recent R&D survey by non-respondents to the CIS4 survey, an additional 400 responses were estimated, giving rise to an overall response rate of 62% (DCSRRP, 2006a: 14). The first best option for avoiding a non-response bias is to achieve a high response rate (Armstrong and Overton, 1977) — a 62% response rate is considered very good in this regard. In the Danish survey, all firms which have had innovative activity have been asked the sources of information questions — in contrast to some other countries, where these questions have been posed to innovators only. Specifically, in addition to the firms which introduced product and process innovation, firms that 'had innovative activities [in terms of product and process innovation] that were still on-going at the end of the year' and 'had innovative activities which were given up over the period 2002–2004' also had to answer to the sources of information questions.

Dependent and key independent variables

We employ two measures to indicate various types of firm-level innovative performance. First, we use a variable that captures the ability of the firm to produce more radical innovations: *innovations new to the firm's market*. This variable is measured as the fraction of the firm's sales relating to products new to the firm's market. On the Danish innovation survey, firms were asked directly whether their enterprise: 'introduced any new or significantly improved products which were also new to the enterprise's market' and what share of total firm sales these products accounted for in 2004 (DCSRRP, 2005: 6). It remains a fundamental limitation of the CIS survey that we only know whether or not a given product is new to the firm's markets, not whether it is new to the world market. It should be noted, however, that Danish firms are highly internationalized with about 68% of the service and manufacturing firms surveyed in the context of CIS3 (not CIS4) having export activity (Laursen, 2008). At the same time, firms competing in the Danish context only are most often exposed to imported products. So in far the majority of the cases (probably close to all cases) the competitors of a given Danish firm are not national (only) and, accordingly, this research design is unlikely to be a major problem.

We incorporated another variable as a measure of more incremental innovation by including a variable for the fraction of the firm's sales from product *innovations only new to the firm* (but not new to the firm's market). Our sales-weighted measure of innovation performance is consistent with Schumpeter's (1912/1934) view, since his notion of innovation not only pertains to the capacity to introduce 'new combinations' in terms, for instance, of new products, but also to the commercial success of those products. In addition, the measure has been widely applied in the previous literature (Mairesse and Mohnen, 2002;

Cassiman and Veugelers, 2006; Laursen and Salter, 2006; Leiponen and Helfat, 2010).

Two of the key independent variables are built on the following question: 'What importance have the following sources of information had as an inspiration for innovation projects?' The questionnaire lists 11 (one internal source and 10 external sources) sources of information for innovation and each of these 11 items are measured on a four-point Likert scale ranging from one to four with one being 'no importance' and four being 'high importance'. Our key variable *Use of Customer Knowledge* is based on the part of the question that pertains to the use of information from customers.

Another key variable is based on the other nine external sources of information for innovation (suppliers; competitors; consultants, private laboratories and research institutions; technological support centers; universities; other public sources; conferences and exhibitions; scientific and technical publications; and industry associations). Following Laursen and Salter (2006), the variable is calculated as follows. As a starting point, each of the nine sources are coded as a binary variable, zero being no use and one being any level of use of the given knowledge source. Subsequently, the nine sources are simply added up so that each firm gets a zero when no knowledge sources are used, while the firm gets the value of nine when all knowledge sources are used. In other words, it is assumed that firms that use higher numbers of sources are more 'open', with respect to search breadth, than firms with lower numbers. Using binary variables and based on a supplementary question on the survey, we examine whether or not firms engaged in formal collaboration arrangements on innovation activities with customers, both regarding *National Customer Collaboration* and *International Customer Collaboration*.

Control variables

We include a measure of R&D intensity, measured as firm R&D expenditure divided by firm sales, in order to control for the effect on R&D on innovative performance. Firm size (expressed in logarithms) is measured by the number of employees (*Log Employee*). We also control for the number of years the firm has been in existence (*Year since Establishment*). Finally, we include 39 industry controls to account for different propensities to innovate across industries (NACE 2-digit industries with some industries aggregated to secure a minimum of five firms in each industry). Industry number 40 is used as the benchmark for the other 39 industries.

Statistical method and results

The dependent variable in the regression model is censored, since the variable is the percentage of innovative sales and, therefore, by definition, ranges between 0 and 100. Accordingly, a Tobit analysis, with a so-called corner solution interpretation, is applied as the vehicle of estimation (see Wooldridge, 2002: 517–549). Descriptive statistics and correlations are given in Table 1. It can be seen that, on average, about 3% of the sales of products made by the firms in the sample can be considered new to the firms' markets. The same is the case for innovations new to the firm only. Regarding multicollinearity, the correlation between External Search Breadth and the Use of Customer Knowledge is high (0.83). However, the results of the models estimated (in Table 2) are all robust to the inclusion of each of the two variables separately. Indeed, removing any variable from all of the six regressions presented produces similar results — the estimations are remarkably stable.

Table 2 contains the results that test our hypotheses. Models I and II include only the variables of key interest plus the 39 industry dummies for each of the two dependent variables: the percentage sales of products new to the firm's market and new to the firm, respectively. Models III and IV include the same estimations, but with all control variables included. We find some evidence in support of

Table 1. Descriptive statistics and correlations

	Variable	Mean	Std dev.	Min.	Max.	1.	2.	3.	4.	5.	6.	7.	8.
1.	New to the firm's market	2.99	10.63	0	100								
2.	Only new to the firm	2.97	9.96	0	100	0.21							
3.	Use of customer knowledge	1.69	1.11	1	4	0.38	0.41						
4.	Breadth	1.91	3.01	0	9	0.38	0.40	0.83					
5.	National customer collaboration	0.10	0.30	0	1	0.28	0.28	0.46	0.48				
6.	International customer collaboration	0.07	0.25	0	1	0.28	0.24	0.41	0.44	0.60			
7.	R&D intensity	0.02	0.11	0	1.97	0.33	0.14	0.23	0.28	0.22	0.21		
8.	Log employees	3.87	1.55	0	9.98	0.04	0.08	0.23	0.27	0.16	0.16	−0.02	
9.	Years since establishment	18.48	17.63	0	183	0.00	0.03	0.07	0.09	0.06	0.06	−0.04	0.28

Notes: N = 3,417
Correlation coefficients ≥ |0.04|, significant at the 5% level

Table 2. Tobit regressions explaining innovative performance

	Model I		Model II		Model III		Model IV		Model V		Model VI	
Independent/dependent variable	**New to the market**		**New to the firm**		**New to the market**		**New to the firm**		**New to the market**		**New to the firm**	
	Coef.	**Std error**	**Coef.**	**Std error**	**Coef.**	**Std error**	**Coef.**	**Std error**	**Coef.**	**Std error**	**Coef.**	**Std error**
Use of customer knowledge	26.13 ***	(5.40)	14.16 **	(4.99)	26.93 ***	(5.14)	13.78 **	(4.95)	54.89 ***	(9.75)	43.92 ***	(9.41)
Use of customer Knowledge squared	−3.57 ***	(0.97)	−1.28 †	(0.90)	−3.97 ***	(0.93)	−1.40 †	(0.89)	-8.19 ***	(1.96)	−6.20 ***	(1.89)
Breadth	12.94 ***	(1.30)	11.75 ***	(1.18)	11.67 ***	(1.23)	11.26 ***	(1.18)	18.95 ***	(2.03)	18.50 ***	(1.92)
Breadth squared	−0.97 ***	(0.12)	−0.85 ***	(0.11)	−0.94 ***	(0.11)	−0.86 ***	(0.11)	−0.39 **	(0.15)	−0.32 **	(0.14)
Use of customer knowledge × breadth									−8.96 ***	(1.89)	−9.13 ***	(1.82)
Use of customer knowledge squared × breadth									1.37 ***	(0.35)	1.44 ***	(0.34)
National customer collaboration					5.49 **	(2.19)	9.25 ***	(2.14)	5.72 **	(2.17)	9.18 ***	(2.12)
International customer collaboration					6.78 **	(2.51)	0.23	(2.45)	6.46 **	(2.50)	0.07	(2.44)
R&D intensity					25.42 ***	(4.77)	−1.27	(5.01)	26.15 ***	(4.76)	−0.54	(5.01)
Log employees					−0.23	(0.57)	0.10	(0.55)	−0.20	(0.57)	0.08	(0.55)
Years since establishment					0.01	(0.04)	0.02	(0.04)	0.01	(0.04)	0.03	(0.04)
Industry dummies (40 industries)	YES		YES		YES		YES		YES		YES	
Constant	−84.34 ***	(5.74)	−67.87 ***	(5.13)	−66.77 ***	(10.45)	−70.79 ***	(11.86)	−93.43	(12.79)	−98.41 ***	(13.83)
/Sigma	27.43	(0.87)	25.56	(0.81)	25.22	(0.79)	24.61	(0.77)	25.09	(0.79)	24.45	(0.77)
McFadden's pseudo R^2	0.16		0.16		0.18		0.17		0.19		0.18	
LR chi^2	1,295 ***		1,293 ***		1,430 ***		1,364 ***		1,464 ***		1,398 ***	
Number of observations	3,478		3,478		3,417		3,417		3,417		3,417	

Note: ***/**/*/† denotes significant at the 0.1, 1, 5 and 10% levels respectively

Hypothesis 1 (The use of customer knowledge in the innovation process is curvilinearly [taking an inverted U-shape] related to innovative performance).

First, the parameter for the Use of Customer Knowledge is significant and positive in explaining innovative performance (for both types of innovation). Accordingly, firms with a (stronger) use of customer knowledge appear to have higher levels of innovative performance. Second, the negative parameter for the squared term is also significant, indicating that when firms become too focused on the use of customer knowledge, negative returns set in. By differentiating, and setting the obtained derivative equal to 0, we obtain the top point of $-\beta_1/(2\beta_2)$, where β_1 is the parameter for the Use of Customer Knowledge, and β_2 is the parameter for the Use of Customer Knowledge Squared. According to this calculation, the top point in the case of Model III in Table 2 is 3.4 and 4.9 in the case of Model IV.

Since the upper range of the Use of Customer Knowledge variable is 4, our model predicts negative returns at the highest level of the Use of Customer Knowledge in the case of innovation new to the firm's market. In the case of innovations only new to the firm (more incremental innovations), our model displays evidence of decreasing return to the Use of Customer Knowledge, but no signs of negative returns (consistent with this, note that Use of Customer Knowledge Squared is only weakly significant in this case). Obviously, our measure of the degree of Use of Customer Knowledge is not very sophisticated, as it is just an indication of the overall importance of the use of customer knowledge, expressed in integer values and ranging from 1 to 4 (the issue of the limitations of this variable is discussed further in the 'Conclusion and Discussion' section at the end of this paper). However, even with this rough measure there is an indication of decreasing returns and, in the case of innovations new to the firm's market, even negative returns for using customer knowledge to a high degree (of course, still much better than not using customer knowledge at all).

With respect to Hypothesis 2 (External search breadth is curvilinearly [taking an inverted U-shape] related to innovative performance), we find Breadth and Breadth Squared significant with the expected signs in both Models III and IV. Indeed, calculations show that the top point is around 6 both in the case of products new to the firm's market and those new to the firm. Since the maximum number of sources is 9, the idea of the inverted U-shape is clearly supported. In other words, the results corroborate the findings by Laursen and Salter (2006).

The proposition of Hypothesis 3 is that the inverted U-shaped relationship between the use of customer knowledge in the innovation process and innovative performance is positively moderated by the breadth of external search above the top point, such that the negative effect of a strong emphasis on customer knowledge is offset by broad external search, using other sources of innovation than customers' knowledge. This hypothesis is tested in Models V and VI. The two models give support to this hypothesis. External search breadth has significant

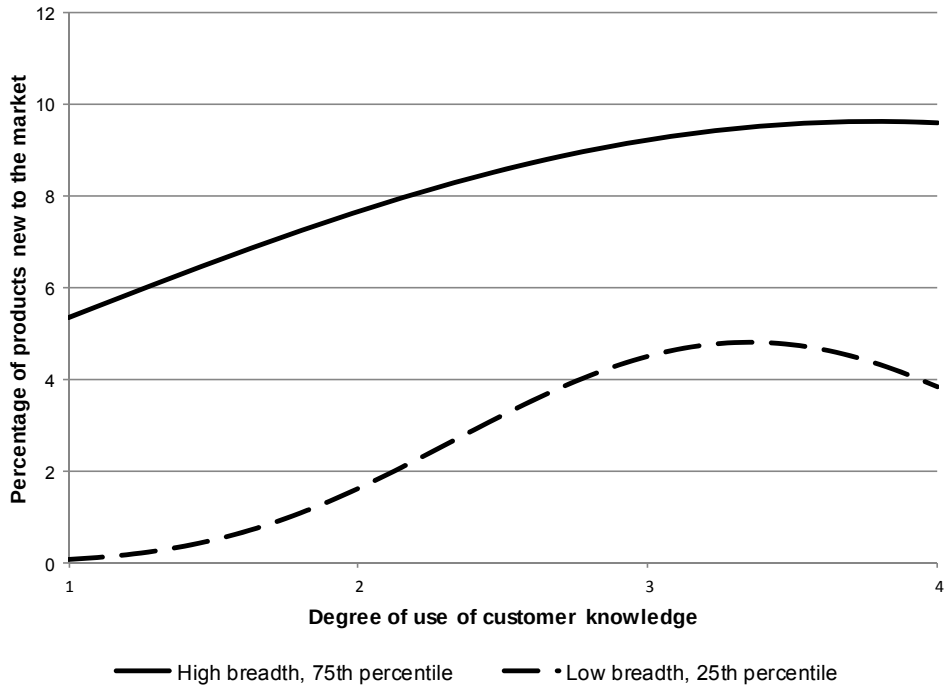

Figure 1. The relationship between the degree of user knowledge and innovation performance (new to the firm's market) as moderated by external search breadth

moderating effects on both the use of Customer Knowledge and Customer Knowledge Squared.

To clarify this complex interaction, we follow Schick and Ponemon (1993) in graphing (in Figure 1) the relationship between the dependent (percentage of innovations new to the firm's market) and key independent (main and squared) variables for low and high values of the moderator variable for the estimations found in Model V. Since we are applying a Tobit model with a corner solution interpretation, it is changes in the unconditional expected values, not linear predictions, that should be reported (for details, see Wooldridge, 2002: 523). We plot the effects at the 25th percentile (zero breadth) and at the 75th percentile (high breadth; that is using four external sources). The two dummies for national and international collaboration are set to zero, while the other variables are set to their sample averages.

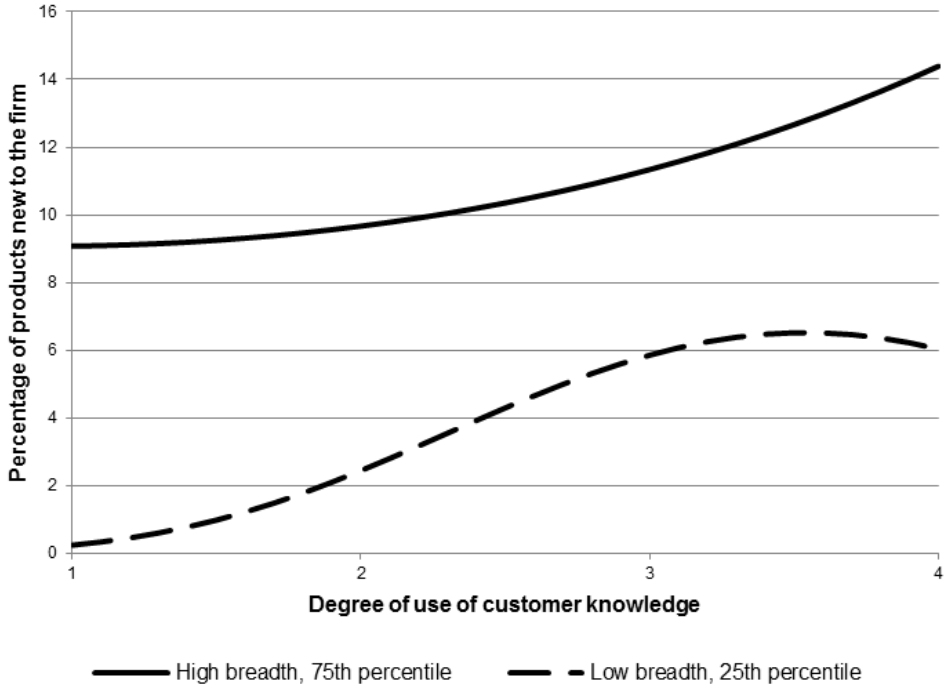

Figure 2. The relationship between the degree of user knowledge and innovation performance (only new to the firm) as moderated by external search breadth

From Figure 1 we can see that the curve for a firm with low external search breadth displays negative returns for values of degrees of use of customer knowledge above the value 3.4. In contrast, a firm with high external search breadth displays only very weak evidence of decreasing returns, and the level of innovative output is much higher. In other words, the negative effect of a high degree of use of customer knowledge is much less pronounced for firms that do broader external search.

Figure 2 plots the same relationship, but in this case the dependent variable is innovations only new to the firm (less radical innovation). The results are similar to the results obtained when looking at more radical innovations (innovations new to the firm's market). However, in the case of less radical innovation, for firms with high search breadth, the relationship between the degree of use of user knowledge and innovation is weakly convex (this relationship is weakly concave in the case of innovations new to the firm's market). This indicates increasing returns in the case of less radical innovation and decreasing returns to the use of customer knowledge in the case of more radical innovation.

In this regard, Laursen and Salter (2006) argue that for more incremental innovation after a dominant design has emerged (Abernathy and Utterback, 1975), a broad variety of sources may be important. After a dominant design has emerged, firms tend to focus on 'fine-tuning' the product by means of incremental improvements which are supported by a broad range of sources of innovation. Relatedly, the number of actors with specific and useful knowledge of the technology increases as the product becomes established. In contrast, more radical innovation typically involves a higher degree of discontinuity in the sources of innovation, since knowledge sources previously used may be outdated in the new context (Christensen, 1997). Accordingly, the use of a few new sources of innovation, used intensively, can be expected to be important in the case of radical innovations. For these reasons, we can speculate that broad search and at the same time extensive use of customer knowledge are more beneficial (given a fixed set of costs) in the case of more incremental innovation as compared to more radical innovation. These benefits may be reflected in the convex curve in Figure 2 in contrast to the concave curve found in Figure 1.

Overall, the findings give support to Hypothesis 4 (Collaboration with national and international customers has a positive association with innovative performance), given that for innovations new to the firm's market, the parameters for both National Customer Collaboration and International Customer Collaboration are positive and significant in explaining innovative performance. In the case of innovations new to the firm, only national collaboration is positive and significant. This finding also gives support Hypothesis 5 (Collaboration with national customers will affect to innovative performance stronger than international collaboration with customers) in the case of innovations only new to the firm. However, the idea that national and international collaboration have the same effect on innovative performance cannot be rejected in the case of innovations new to the firm's market.

Conclusion and discussion

We began this paper by noting that the innovation literature has found that customers' knowledge often plays a central role in the production of innovations. Less attention has been given to the potential downsides of working with customers' knowledge, although this phenomenon has not been completely overlooked. In this paper we have found that using customers as a source of innovation is significantly linked to higher levels of innovative sales. In the case of innovations new to the firm's market, emphasizing customers to a high degree, however, seems to have less effect on innovative sales as compared to emphasizing customers to a medium degree. In other words, we found evidence of negative returns of the involvement of customer knowledge beyond a certain point.

In the case of innovations only new to the firm, the negative sides of using customer knowledge at high levels seems less strong as the curve does not bend inside the range of the customer knowledge variable. Indeed, it seems that the costs associated with using customers' knowledge to a high degree is higher in the case of more radical innovation — a situation in which it is central to search in genuinely new directions. Relying heavily on customers' knowledge may prevent firms from searching in such new directions. However, in the case of more incremental innovation, the penalty for relying heavily on customers' knowledge is less heavy. This finding may have to do with the frequently made observation that myopia — in our case related to focusing on customers — is more likely to hurt explorative efforts (as reflected in innovation new to the firm's market) in comparison to more exploitative efforts (as reflected in innovation only new to the firm).

We found support for Lundvall's idea that local (national) collaboration with customers concerning innovation matters more for product innovation than international collaboration with customers, but only in the case of more incremental innovation

We also found that the inverted U-shaped relationship is positively moderated by the search breadth in terms of the number of other external knowledge sources (other than the use of customer knowledge). This result is true both for innovations new to the firm and for innovations new to the firm's market. In other words, some of the negative sides of working with customer knowledge are offset, when the focal firm performs broader (explorative) external search by having a relatively high search breadth.

Furthermore, we found support for Lundvall's idea that local (national) collaboration with customers concerning innovation matters more for product innovation than international collaboration with customers, but only in the case of more incremental innovation (innovation only new to the firm). In the case of more radical innovation (innovation new to the firm's market), our results indicated that both national and international collaboration with customers for innovation seem to matter equally for innovative sales. The relatively higher importance of formal international customer collaboration in the case of more radical innovation in comparison with more incremental innovation can be due to the fact that the opportunity set offered by national collaborators may be somewhat limited (especially in the small-country case such as ours), and hence there is additional leverage to be gained from international customer collaboration, even if it is much more costly to collaborate over longer cultural and geographical distances as suggested by Lundvall (1988). In other words, when the knowledge required is not available locally, firms look outside the local/national market even if communication is more difficult.

This paper has limitations. First and foremost, the customer knowledge variable has limitations, simple as it is. Future research should aim at developing much more sophisticated measures. One such measure could involve looking at the role of customers at various stages of the innovation process (e.g. idea generation, implementation and fine-tuning stages of the product development process). Such a measure would allow for the calculation of a continuous independent variable that would make the empirical interpretation of the results somewhat more clear-cut.

In addition, in our set-up, there is no indication of the amount of time a focal firm has interacted with its customers, and no indication of the number and diversity of clients in terms of types of services of goods developed. Intuitively one would imagine that the problem of inertia or myopic learning would be most present in the case of a focal firm working for just one or a few clients over a long period of time. Future studies should also make attempts to account for the issue of reciprocity and trust in producer–customer relationships as strongly emphasized by Lundvall in his 1988 paper (and elsewhere). This paper has not really addressed this important aspect. However, despite these limitations, this paper can be seen as a first step in the direction of getting a better understanding of not only the advantages, but also the downsides of using customer knowledge in the making of innovations.

This paper has important policy implications as several governments in the EU (including Denmark, Finland and the UK) are either looking at — or have already implemented — innovation policies aiming at nursing user-driven innovation. Assuming that such policies can be somewhat effective, this paper has underlined the fact that policies narrowly aimed at promoting the use of user knowledge in innovation may be mislead, given that 'average' user knowledge may prevent more radical solutions to problems in the innovation process. To be more precise, the use of customer knowledge appears much more effective when it is utilized in conjunction with other sources of innovation. Accordingly, policies aimed at promoting innovation should be broader and somewhat more 'systemic' in nature. Indeed, this latter viewpoint is in line with Lundvall's (1992a) ideas regarding systems of innovation.

Note

1. An important exception is the lead-user literature (Von Hippel, 1986), in which is argued that the type of user matters significantly. In particular, it is has been found that lead users with certain characteristics (they are early adopters of the product or service; they experience the need for a given innovation earlier than the majority of the target market; and they are users who expect attractive innovation-related benefits from a solution to a problem) are most likely to be important sources of innovation. However, this literature has not addressed the issue of how a too strong focus on customers can be offset by other types of exploratory search on behalf of the innovating firm (for an excellent overview of the user-innovation literature, see Bogers *et al.*, 2010).

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