International Journal of Innovation Management
Vol. 13, No. 2 (June 2009) pp. 1–24

ICP Imperial College Press
www.icpress.co.uk

TOWARD A DYNAMIC PERSPECTIVE ON OPEN INNOVATION: A LONGITUDINAL ASSESSMENT OF THE ADOPTION OF INTERNAL AND EXTERNAL INNOVATION STRATEGIES IN THE NETHERLANDS

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Received
Revised
Accepted

The purpose of this paper is to contribute to a more dynamic perspective on open innovation by conducting a longitudinal analysis of the adoption of open innovation strategies. In order to do so, we rely on three comparable waves of the Dutch Community Innovation Survey, which were conducted in 1996, 2000 and 2004. The contributions of this study are twofold. First, this study is to our knowledge the first one to explicitly provide large-scale evidence of a paradigm shift from a closed to an open innovation model is taking place. At the same time, we provide evidence that this paradigm shift tends to occur in shocks instead of manifesting itself as a continuous process over time. Moreover, we show that the timing of these shocks differs across industries. Second, this study supports the assumption that internal and external innovation strategies are complements instead of substitutes.

Keywords: Open innovation; external innovation; internal innovation.

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Introduction

Based on close observation of a small number of companies, Chesbrough (2003a) describes an innovation paradigm shift from a closed to an open innovation model, which is characterized by the use of purposive inflows and outflows of knowledge to both accelerate internal innovation and expand the markets for external use of innovation. Recently, numerous companies (i.e. IBM, Intel, P&G) have started to adopt the concept of open innovation. Nowadays, some managers even argue that "open innovation is no longer a source of competitive advantage, it has become a competitive necessity." At the same time, academic research on the concept of innovation is also proliferating. This open innovation research is dominated by case studies on how open innovation is implemented and organized within firms (e.g. Dodgson *et al.*, 2006; Chesbrough and Rosenbloom, 2002), and survey studies on the adoption and performance implications of open innovation strategies (e.g. Laursen and Salter, 2006; Lichtenthaler, 2008).

Although these existing open innovation studies have contributed to our understanding of the open innovation model, Chesbrough *et al.* (2006) emphasize that these studies present a quite static perspective on open innovation, providing limited insights in how open innovation evolves over time. In a similar vein, Laursen and Salter (2006: 147) conclude that: "until greater research is undertaken on the nature of search over time, the full implications of the movement towards 'open innovation' will not be fully understood." The purpose of this paper is therefore to contribute to a more dynamic perspective on open innovation by conducting a longitudinal analysis of the adoption of open innovation strategies. In order to do so, we rely on three comparable waves of the Dutch Community Innovation Survey, which were conducted in 1996, 2000 and 2004.

The contributions of this study are twofold. First, this study is to our knowledge the first one to explicitly provide large-scale evidence of Chesbrough's (2003a) assumption that a paradigm shift from a closed to an open innovation model is taking place. At the same time, we provide evidence that this paradigm shift tends to occur in shocks instead of manifesting itself as a continuous process over time. Moreover, we show that the timing of these shocks differs across industries. Second, this study supports the assumption provided by Chesbrough (2003a) that internal and external innovation strategies are complements instead of substitutes.

The remainder of this paper consists of four sections. First, we position our study in the existing literature on open innovation. Subsequently, we discuss our methodology. Next, we describe our main results. Finally, we discuss the implications of our results, identify the main limitations of this study and suggest interesting avenues for future research.

Literature Review

Closed versus open innovation

Innovation has long been acknowledged as one of the critical driving forces in enhancing social welfare. Likewise, innovation is seen as crucial for the long term survival and growth of the firm (Baumol, 2002; Schumpeter, 1939). According to Chesbrough (2003a), we are experiencing a paradigm shift in how companies manage and organize their innovation activities. In particular, he argues that companies are shifting from a closed to an open innovation model (see Fig. 1).

In a closed innovation model, firms internalize their firm-specific R&D activities, and commercialize them through internal development, manufacturing, and distribution processes. This model considers R&D as an inherent part of a vertically integrated system within firms. Within such a closed innovation model, the focus is on securing "the best and the brightest", and then trusting that these people will come up with valuable new innovations (Chesbrough, 2003b; Chesbrough, 2006).

In contrast, an open innovation model is characterized by the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. This model treats R&D as an open system in which external ides and external paths to market are placed on the same level of importance as that reserved for internal ideas and paths to market. Adopting an open innovation model, firms acknowledge that "not all of the smart people work for us, so we must find and tap into the knowledge and expertise of bright individuals outside our company" (Chesbrough, 2003b: 38).

Empirical research on open innovation: a state-of-the-art

During the past five years, the open innovation model has become increasingly popular among innovation managers, CEOs and policy makers. Following its widespread dispersion in practice, academic research on open innovation has also been proliferating. Examining the exisisting innovation literature, two streams of open innovation research can be identified.

The first stream of open innovation research focuses on the implementation of open innovation within firms. This research stream is dominated by case studies that provide in-depth insights into motivations, processes, and outcomes of implementing an open innovation model. Chesbrough himself illustrates how high-tech companies such as Xerox (Chesbrough and Rosenbloom, 2002) and IBM (Chesbrough and Appleyard, 2007) adopt open innovation models. Both Dodgson *et al.* (2006) and Huston and Sakkab (2006) provide a detailed description of the implementation of open innovation at Procter & Gamble. They describe how Procter & Gamble launched its famous "Connect and Develop" innovation strategy in order

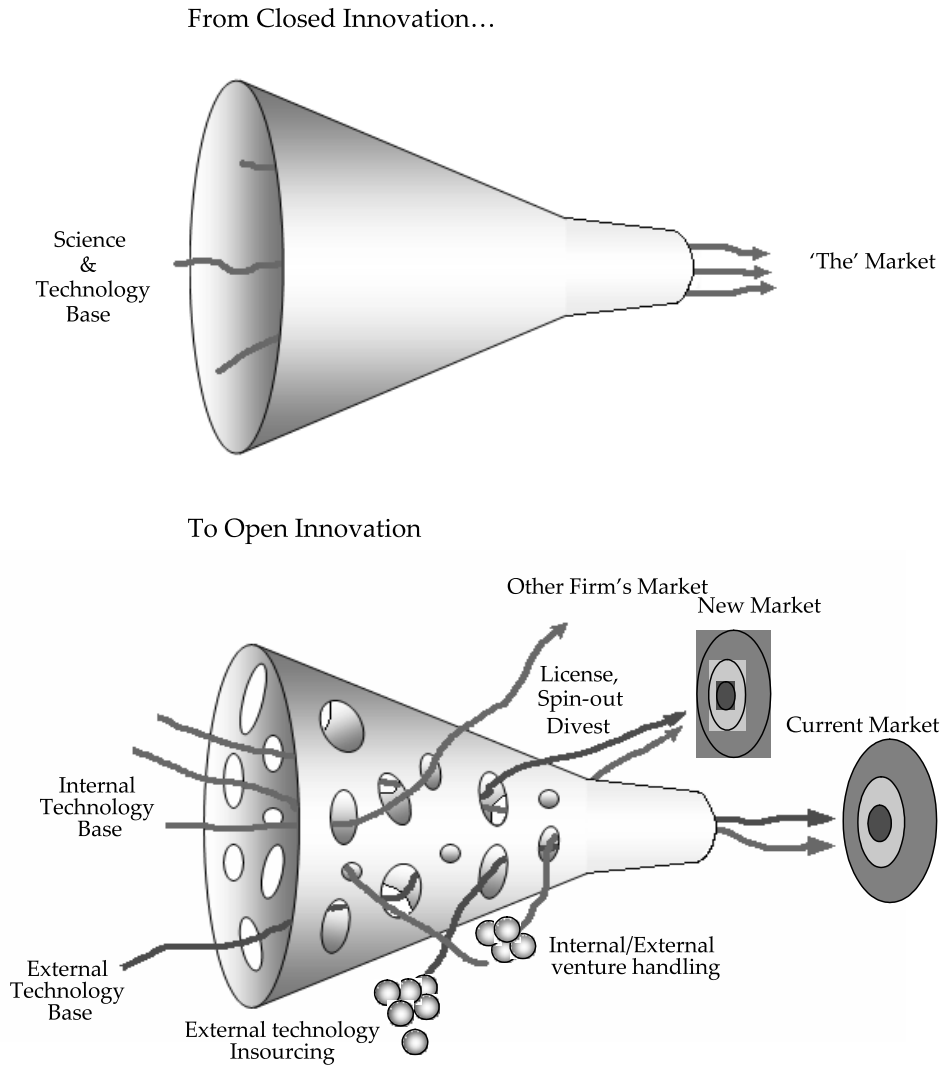

Fig. 1. From a closed to an open innovation model (based on Chesbrough, 2003b).

to revitalize growth through innovation. In addition, Dodgson *et al.* (2006) show that the implementation of this open innovation strategy was accompanied by the adoption of new technologies for data mining, simulation, prototyping and visual representation. According to Huston and Sakkab (2006), the implementation of the Connect and Develop strategy allowed Procter & Gamble to drastically improve its innovation success as well as its R&D productivity. Other case studies have focused on the implementation of particular aspects of the open innovation model such as integrating customers into the innovation process (Enkel *et al.*, 2005; Gassmann

et al., 2006), investing in open-source software (West and Gallagher, 2006), integrating external technology exploitation in strategic technology-planning processes (Lichtenthaler, 2008), and managing alliances and partnerships (Chiaromonte, 2006; Faems *et al.*, 2008).

The second open innovation research stream concerns cross-sectional survey studies on the open innovation phenomenon. Based on a cross-sectional survey study of 154 technology-oriented companies in Germany, Austria and Switzerland, Lichtenthaler (2008) examines the extent to which companies adopt the open innovation model. Conducting a cluster analysis, he reports that the vast majority of respondent firms represent closed innovators or firms with very limited external technology acquisition and external technology exploitation. He also observes that open innovation is mainly driven by larger companies and that diversified firms tend to externally leverage technologies more actively than focused firms. Conducting a survey study on 59 Finnish firms, Salmi *et al.* (2008) come to similar conclusions. They observe that Finnish firms rarely have explicit open innovation strategies. In addition, their findings indicate that firms mainly focus on outside-in open innovation processes (i.e. acquiring knowledge from outside partners) and largely ignore inside-out open innovation processes (i.e. selling knowledge to outside partners).

Other scholars rely on cross-sectional survey research to examine the performance implications of adopting open innovation strategies. In particular they assess the extent to which the innovation performance of firms is influenced by (1) the reliance on external information sources (Laursen and Salter, 2006); and (2) the presence/absence of formal collaboration with external partners (Belderbos *et al.*, 2004; Faems *et al.*, 2005). Laursen and Salter (2006) provide evidence that both the number of external information sources (i.e. breadth of external search) and the extent to which firms draw deeply from these different external information sources (i.e. depth of external sources) are curvilinearly related to innovation performance. Belderbos *et al.* (2004) and Faems *et al.* (2005) show that, whereas formal collaboration with customers and/or suppliers positively influences incremental innovation performance, formal collaboration with universities and/or research institutes positively influences radical innovation performance.

In sum, existing survey studies on open innovation show that the actual adaptation of the open innovation model is still rather low. At the same time, some studies provide clear indications that engaging in open innovation strategies has important advantages in terms of stimulating innovation performance.

Need for a dynamic perspective on open innovation

Although academic research has become increasingly interested in the concept of open innovation, Chesbrough (2006: 3) acknowledges that "it is far too soon to

claim that the paradigm of open innovation will make an enduring contribution to our understanding of innovation." In addition, he emphasizes that, if open innovation wants to become more than the next managerial hype, additional research on the open innovation concept is necessary. West *et al.* (2006) therefore formulate a future research agenda that should allow to further explore the theoretical foundations, implications and limitations of the open innovation model. Among other things, West *et al.* (2006) emphasize the need for a more dynamic perspective on open innovation. For instance, they argue that, whereas existing survey studies provide a cross-sectional analysis of the adoption and performance consequences of open innovation, more longitudinal designs that allow to map the evolution of open innovation over time are needed. The purpose of this study is therefore to conduct a longitudinal analysis of the extent to which firms adopt open innovation strategies.

Methodology

Data

In the Netherlands, there is a long tradition of innovation surveys. Since 1992, the Statistics Netherlands (CBS) has been conducting the innovation survey. In 1996, the questionnaire was harmonized according the guidelines of EuroStat and every four years a harmonized questionnaire is sent to approximately 14,000 firms in the Netherlands. At present, we have three waves of CIS-data to our disposal, CIS2 covering the period of 1994–1996, CIS3 (1998–2000) and CIS4 (2002–2004).

After merging at the firm level of the three waves of CIS-data, the dataset encompasses 24,801 observations. From this dataset, we selected firms with 10 employees or more and excluded firms in the primary sector, leaving 16,384 observations in the database. Only the firms that introduced at least one product or process innovation needed to fill out all questions in the different waves of the CIS survey. In this study, the analysis is therefore further restricted to firms that introduced at least one product or process innovation between 1994 and 2004. After selecting the innovative firms, 9,928 observations were left in the database, representing the answers of 7,671 unique firms. In this, three waves panel dataset 397 firms are present in all three waves, 1,094 firms are present in two waves and 6,180 firms are present in only one wave. The lower part of Table 1 shows the structure of the panel dataset. In this study, we report results on both the full dataset and the restricted dataset (i.e. only those firms that answered in all three waves).

Variables

Reliance on external and internal information sources. In the Community Innovation Survey (CIS), one of the questions deals with the sources of innovation.

Table 1. Construction of the panel dataset.

	Step 0 Separate files	Step 1 After merging	Step 2 Selection and removing duplicates	Step 3 Reshape: panel data and selection of innovative firms
		Number of observations		
CIS2	10,670			
CIS3	10,729			
CIS4	10,829			
CIS2+3+4		24,801		
Cross section (all firms)			16,384	
Panel data: firms innovative at least once *of which in*:				9,928
CIS2 (1996)				3,852
CIS3 (2000)				3,255
CIS4 (2004)				2,821
Panel structure	First occurrence in panel:			
Number of occurrences	1996	2000	2004	Total
1	2,740	1,764	1,676	6,180
2	715	379	0	1,094
3	397	0	0	397
Total number of individual innovative firms				7,671

Firms were asked to indicate the importance of particular external sources of innovation such as (1) suppliers of equipment, materials, components, or software, (2) clients or customers, (3) competitors or other enterprises in your sector, (4) universities or other higher education institutions, and (5) conferences, trade fairs and exhibitions. The degree of importance is measured on a 4-point scale: high (score = 3), medium (score = 2), low (score = 1) or not used (score = 0). Based on this question, we constructed a variable that indicates the importance of external information sources for the firm's innovation activities. In particular, we summed the scores of all external sources of information. It needs to be noticed that the amount of external sources of innovation and the wording of the related question varied between the successive CIS-questionnaires. In order to address this issue, we standardized the score between zero and one. In this way, the scores were comparable across different waves. In a previous study, Laursen and Salter (2004) constructed a similar variable. According to these scholars, this proxy variable adequately reflects the degree of openness of the innovation strategy of a firm.

In the different CIS surveys, companies were also asked to indicate the importance of internal information sources (i.e. sources within the enterprise or enterprise group) for innovation activities. Based on this question, we also calculated a standardized score, reflecting the importance of internal information sources. Finally, we also constructed an indicator, measuring the relative importance of external information sources versus internal information sources.

External and internal collaboration. Formal collaboration with external partners for innovation activities has been recognized as a viable mechanism to accomplish a shift towards an open innovation model (Chesbrough, 2003a; Faems *et al.*, 2005; Poot, 2004). In the CIS surveys, organizations had to indicate whether they had engaged in formal collaboration with different kinds of partners in different kinds of geographical locations. Out of the seven different types of collaborative partners, we constructed four different modes of collaboration (Cassiman and Veugelers, 2002). The first mode is collaboration with other enterprises within the enterprise group. We call this mode internal collaboration. The second mode of collaboration is with competitors, called horizontal collaboration; the third mode is with suppliers of equipment, materials, components, or software and clients or customers, called vertical collaboration; and the fourth mode is collaboration with consultancies, universities, other research institutes, called knowledge-intensive collaboration. For each mode of collaboration, a score has been calculated by summing all the tick marks thus treating the different locations equally and then scaled the score to a range between 0 and 10.

Industry variables. Industry membership can substantially influences the innovation strategies and practices of firms (Malerba, 2005; Pavitt, 1984; Veugelers, 1997). Several studies (e.g. Hagedoorn, 1993, 2002), for instance, suggest that the adoption of collaborative R&D strategies is associated with high-tech sectors, where learning and flexibility are important features of the competitive landscape. However, Chesbrough and Crowther (2006) recently reported that open innovation is not only prevalent in high-tech industries, but also manifests itself in more traditional and mature industries. In addition, Lichtenthaler (2008) came to the conclusion that industry membership does not influence the adoption of open innovation. Based on this observation, he concluded that "the degree of open innovation seems to be mainly determined by the individual strategic choice of a company rather than by industry characteristics" (Lichtenthaler, 2008: 155). In our analyses, we wanted to look at differences between different industries in terms of the evolution of open innovation strategies. Table 2 provides an overview of the frequencies for each industry for the restricted dataset.

Table 2. Overview of industry membership for restricted dataset ($N = 397$).

Sector	Nace (rev 1.1)	Frequency	%
Food and Textile	15–19	38	9.6%
Wood and Paper	20–21	26	6.5%
Fossil fuels and chemicals	23–24	35	8.8%
Rubber and plastic products	25	20	5.0%
Metals and metal products	27–28	44	11.1%
Machinery	29	45	11.3%
Electrical and optical equipment	30–33	22	5.5%
Transport equipment	34–35	16	4.0%
Other manufacturing activities	26, 36–37	25	6.3%
Construction	45	17	4.3%
Services	22, 50–99	109	27.5%
Total		397	100.0%

Results

In this section, we discuss the main results of our analyses. First, we discuss the evolution of open innovation in terms of the extent to which firms rely on external and internal information sources for their innovation activities. Second, we report our findings on the evolution of open innovation in terms of the extent to which firms rely on formal collaboration with external and internal partners for their innovation activities.

Evolution of reliance on external and internal information sources

Table 3 provides an overview of the evolution of the means on (1) reliance on external sources of information, (2) reliance on internal sources of information and (3) the ratio of reliance of external versus internal information sources for innovation activities for the full dataset. These results suggest that the extent to which firms rely on external information sources to support innovation activities steadily increased over time.

Table 4 reports on the same variables for the restricted dataset (i.e. only those firms that participated in each wave). For the restricted dataset, we were able to conduct T-tests, allowing for the identification of significant shifts between the different waves. When we take a look at the total amount of cases in this restricted dataset, we observe a significantly positive shift in the reliance on external information sources between the first and the second wave as well as the second and the third wave. The results of the GLM analysis, which are reported in Table 5, provide additional evidence for this increasing trend across the three waves.

Table 3. Reliance on external sources of information (standardized between 0 and 1), and the ratio of reliance on external sources of information versus (numerator) versus reliance on internal sources of information (denominator) for innovation activities (1996: $N = 3,852$, 2000: $N = 3,255$, 2004: $N = 2,821$).

	Reliance on external sources of information			Reliance on internal sources			Ratio of external sources versus internal sources of innovation		
	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)
nace 2 digit		Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)	
15–16	0.271	0.344	0.397	0.539	0.557	0.733	0.537	0.344	0.397
	(0.157)	(0.179)	(0.173)	(Std Dev)	(0.267)	(0.287)	(0.386)	(0.179)	(0.173)
17–19	0.267	0.329	0.648	0.456	0.478	0.78	0.613	0.785	0.648
	(0.173)	(0.19)	(0.272)	(0.239)	(0.214)	(0.219)	(0.528)	(0.642)	(0.272)
20–21	0.254	0.323	0.403	0.491	0.528	0.777	0.509	0.634	0.558
	(0.147)	(0.188)	(0.162)	(0.221)	(0.253)	(0.239)	(0.359)	(0.465)	(0.318)
22	0.24	0.28	0.359	0.387	0.445	0.656	0.525	0.628	0.527
	(0.139)	(0.166)	(0.158)	(0.233)	(0.254)	(0.316)	(0.459)	(0.579)	(0.378)
23–24	0.291	0.319	0.319	0.601	0.632	0.822	0.525	0.564	0.526
	(0.145)	(0.195)	(0.195)	(0.257)	(0.249)	(0.23)	(0.378)	(0.469)	(0.303)
25	0.303	0.348	0.431	0.541	0.584	0.762	0.606	0.658	0.431
	(0.143)	(0.169)	(0.153)	(0.249)	(0.224)	(0.259)	(0.404)	(0.489)	(0.153)
27, 28	0.264	0.298	0.363	0.446	0.526	0.704	0.59	0.585	0.509
	(0.142)	(0.17)	(0.169)	(0.225)	(0.225)	(0.287)	(0.388)	(0.384)	(0.332)
29	0.284	0.346	0.419	0.511	0.523	0.643	0.607	0.702	0.547
	(0.152)	(0.18)	(0.166)	(0.221)	(0.223)	(0.219)	(0.419)	(0.5)	(0.313)
30–33	0.309	0.367	0.437	0.509	0.588	0.802	0.681	0.367	0.437
	(0.155)	(0.19)	(0.177)	(0.228)	(0.216)	(0.226)	(0.469)	(0.19)	(0.177)

Table 3. (*Continued*)

	Reliance on external sources of information			Reliance on internal sources			Ratio of external sources versus internal sources of innovation		
	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)
nace 2 digit		Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)	
34–35	0.284 (0.175)	0.362 (0.175)	0.425 (0.175)	0.516 (0.228)	0.562 (0.227)	0.785 (0.269)	0.569 (0.37)	0.694 (0.452)	0.549 (0.328)
26, 36, 37	0.254 (0.138)	0.327 (0.18)	0.394 (0.164)	0.504 (0.246)	0.506 (0.229)	0.714 (0.281)	0.514 (0.342)	0.327 (0.18)	0.394 (0.164)
45	0.249 (0.15)	0.289 (0.176)	0.354 (0.183)	0.367 (0.233)	0.448 (0.277)	0.693 (0.306)	0.565 (0.502)	0.577 (0.502)	0.354 (0.183)
51	0.274 (0.155)	0.312 (0.18)	0.382 (0.173)	0.547 (0.269)	0.544 (0.282)	0.781 (0.259)	0.511 (0.408)	0.312 (0.18)	0.382 (0.173)
50, 52	0.242 (0.145)	0.268 (0.189)	0.301 (0.165)	0.48 (0.264)	0.462 (0.305)	0.664 (0.328)	0.512 (0.472)	0.475 (0.467)	0.405 (0.333)
60–64	0.218 (0.145)	0.283 (0.163)	0.365 (0.177)	0.473 (0.294)	0.539 (0.252)	0.719 (0.299)	0.47 (0.401)	0.513 (0.362)	0.365 (0.177)
72	0.304 (0.145)	0.309 (0.159)	0.429 (0.175)	0.574 (0.265)	0.594 (0.229)	0.82 (0.217)	0.567 (0.37)	0.571 (0.397)	0.566 (0.296)
65–67, 70, 71, 73, 74	0.251 (0.152)	0.286 (0.177)	0.368 (0.171)	0.501 (0.234)	0.519 (0.253)	0.748 (0.296)	0.524 (0.422)	0.573 (0.457)	0.496 (0.355)
55, 75–85, 90–99	0.268 (0.169)	0.266 (0.187)	0.359 (0.171)	0.517 (0.233)	0.522 (0.267)	0.608 (0.328)	0.512 (0.384)	0.492 (0.416)	0.517 (0.343)
Total	0.265 (0.152)	0.31 (0.18)	0.386 (0.174)	0.497 (0.254)	0.529 (0.257)	0.749 (0.28)	0.544 (0.421)	0.603 (0.471)	0.517 (0.326)

Table 4. Reliance on external sources of information (score of open innovation, standardized between 0 and 1), and the ratio of reliance on external sources of information versus (numerator) versus reliance on internal sources of information (denominator) for innovation activities ($N = 397$).

	Reliance on external sources of information			Reliance on internal sources of information			Ratio of external sources versus internal sources of innovation		
	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)
	Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)		
Food and Textile	0.31 (0.193)	0.339 (0.19)	**0.447***** (0.159)	0.614 (0.198)	0.588 (0.235)	**0.798***** (0.263)	0.529 (0.334)	0.648 (0.49)	0.567 (0.252)
Wood and Paper	0.326 (0.125)	**0.413*** (0.209)	0.438 (0.16)	0.538 (0.184)	0.596 (0.237)	**0.808***** (0.253)	0.661 (0.345)	0.758 (0.397)	0.63 (0.371)
Fossil fuels and chemicals	0.286 (0.134)	0.325 (0.193)	**0.42**** (0.187)	0.748 (0.164)	0.752 (0.2)	**0.857**** (0.203)	0.393 (0.19)	0.437 (0.241)	0.512 (0.248)
Rubber and plastic products	0.312 (0.186)	0.363 (0.178)	0.408 (0.167)	0.625 (0.229)	0.633 (0.176)	**0.8**** (0.251)	0.599 (0.475)	0.638 (0.435)	0.48 (0.249)
Metals and metal products	0.293 (0.129)	0.342 (0.203)	**0.41*** (0.131)	0.47 (0.198)	**0.549*** (0.229)	**0.78***** (0.189)	0.661 (0.413)	0.698 (0.527)	0.558 (0.24)
Machinery	0.329 (0.137)	0.354 (0.167)	**0.473***** (0.136)	0.578 (0.18)	0.552 (0.246)	**0.867***** (0.206)	0.623 (0.305)	0.724 (0.517)	**0.581*** (0.254)
Electrical and optical equipment	0.416 (0.129)	0.47 (0.179)	0.491 (0.157)	0.568 (0.16)	0.621 (0.18)	**0.848***** (0.199)	0.793 (0.349)	0.819 (0.43)	**0.611*** (0.299)
Transport equipment	0.389 (0.163)	0.397 (0.198)	0.486 (0.158)	0.625 (0.313)	0.615 (0.249)	**0.875***** (0.206)	0.667 (0.378)	0.692 (0.327)	0.623 (0.425)

Table 4. (*Continued*)

	Reliance on external sources of information			Reliance on internal sources of information			Ratio of external sources versus internal sources of innovation		
	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)	CIS I ('94–'96)	CIS II ('98–'00)	CIS III ('02–'04)
	Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)		
Other manufacturing activities	0.297	**0.395****	0.41	0.6	0.58	0.693	0.553	**0.777****	0.596
	(0.138)	(0.164)	(0.192)	(0.226)	(0.246)	(0.287)	(0.326)	(0.47)	(0.516)
Construction	0.296	**0.381***	0.418	0.51	0.48	**0.863*****	0.626	0.794	**0.541***
	(0.124)	(0.154)	(0.158)	(0.309)	(0.249)	(0.206)	(0.389)	(0.511)	(0.328)
Services	0.279	0.314	**0.399*****	0.58	0.578	**0.844*****	0.526	0.592	**0.507***
	(0.177)	(0.189)	(0.171)	(0.232)	(0.222)	(0.211)	(0.437)	(0.422)	(0.28)
Total	0.308	**0.354*****	**0.428*****	0.584	0.592	**0.825*****	0.579	**0.661*****	**0.551*****
	(0.158)	(0.189)	(0.163)	(0.223)	(0.23)	(0.224)	(0.382)	(0.45)	(0.303)

*, ** and *** denote significant differences from the previous wave at the level of 10%, 5% and 1% respectively.

Table 5. Results GLM test (restricted dataset).

The GLM Procedure: Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects: H0, no effect

	Source	DF	Type III	Mean Square	F Value	Pr > F
Reliance on external sources	time	2	0.634	0.317	13.85	<**0.0001**
	time*sbi2	2	0.001	0.001	0.03	0.9741
	Error(time)	790	18.086	0.023		
Ratio of external versus internal sources	time	2	0.744	0.372	3.28	0.038
	time*sbi2	2	0.055	0.028	0.24	**0.7845**
	Error(time)	754	85.466	0.113		

When we take a look at the individual industries (see Table 5), some important additional observations can be made. We notice that in three industries (i.e. rubber and fibres, electrical equipment, automotive), the reliance on external sources of information did not significantly change across the three observed waves. In three other industries (i.e. wood and paper, other manufacturing activities, construction), a significant shift was observed between the first and the second wave, meaning that, within these industries, firms relied significantly more on external sources of information in the period 1998–2000 than in the period 1994–1996. In the six remaining industries (i.e. food, textile, chemicals, metal and metal products, machines and equipment, services), a significant shift was observed between the second and the third wave, indicating that, within these industries, firms relied significantly more on external sources of information in the period 2002–2004 than in the period 1998–2002. It needs to be stressed that (1) no single industry reported two significant shifts over time; and (2) no single industry reported negative shifts with respect to reliance on external sources of information.

Table 5 also indicates that, for most of the industries, significant changes in the reliance on external sources of information did not significantly change the ratio of the reliance on external versus internal sources of information. The machines and equipment industry and the services industry are exceptions in this respect. In these two industries, the significant shift concerning reliance on external sources of information between the second and the third wave corresponded with a significant shift in the ratio of external versus internal sources of information. However, this shift in the ratio is significantly negative, meaning that the reliance on internal sources of information increased even more that the reliance on external sources of information. In sum, our data provide evidence that increased reliance on external information sources did not decrease the reliance on internal information sources.

Evolution of external and internal collaboration

Table 6 provides an overview of the evolution of the means on (1) the degree of internal collaboration; (2) the degree of horizontal collaboration; (3) the degree of vertical collaboration, and (4) the degree of knowledge collaboration.

Table 7 presents an overview of these collaboration variables for the restricted dataset. Again, we conducted T-tests to search for significant shifts between the different waves. Comparing the first and the second wave, it can be concluded that the degree of internal collaboration, horizontal collaboration and vertical collaboration remained quite stable across these two periods. We only observed a positive significant shift for the knowledge collaboration variable, meaning that firms relied significantly more on collaboration with consultants, universities or other knowledge institutes in the period 1998–2000 than in the period 1994–1996. At the same time, this latter significant effect was only observed on the level of the total number of firms, and did not manifest itself on the level of individual industries.

Comparing the second and third wave, numerous significant shifts in the degree of vertical collaboration and knowledge collaboration can be observed. For all industries, firms relied significantly more on vertical collaboration and knowledge collaboration in the period 2002–2004 than in the period 1998–2000. The only exception is the automotive industry, where we did not observe a significant shift between the second and third wave with respect to knowledge collaboration. At the same time, much less significant shifts between the second and third wave were observed for the horizontal collaboration variable. Only in the paper and wood and the chemicals industry was a positive significant shift observed, indicating that, within these two industries, firms relied increasingly more on collaboration with competitors in the period 2002–2004 than in the period 1998–2000. For the majority of the industries, we also observed a significant shift between the second and third wave concerning the degree of internal collaboration. Except for the automotive and electronic equipment industry, we observed that firms relied increasingly more on collaboration with other firms within their holding in the period 2002–2004 than in the period 1998–2000. These latter findings indicate that increased reliance on external partners for innovation activities does not reduce the reliance on internal partners for innovation activities.

Discussion and Conclusion

In this section, we discuss the main findings of our study, present its main limitations and suggest interesting avenues for future research.

Table 6. Evolution of external and internal collaboration; scores are standardized between 0 and 10 (1996: $N = 3,852$, 2000: $N = 3,255$, 2004: $N = 2,821$).

	Collaboration with firms within the holding (internal collaboration)			Collaboration with competitors (horizontal collaboration)			Collaboration with suppliers and customers (vertical collaboration)			Collaboration with consultancies, universities, and other research institutes (knowledge collaboration)		
	Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)		
Industry	1996	2000	2004	1996	2000	2004	1996	2000	2004	1996	2000	2004
15–16	0.495	0.365	1.003	0.228	0.125	0.381	0.505	0.254	1.282	0.264	0.107	0.584
	(1.16)	(1.172)	(1.797)	(0.778)	(0.503)	(1.177)	(1.052)	(0.737)	(1.788)	(0.669)	(0.348)	(1.122)
17–19	0.184	0.353	1.037	0.299	0.321	0.793	0.517	0.513	1.646	0.184	0.184	0.996
	(0.724)	(0.831)	(1.476)	(0.941)	(0.876)	(1.525)	(1.209)	(1.097)	(1.733)	(0.462)	(0.462)	(1.321)
20–21	0.403	0.331	1.291	0.292	0.152	0.495	0.549	0.406	1.552	0.204	0.141	0.659
	(1.02)	(0.733)	(1.949)	(0.884)	(0.527)	(1.303)	(1.256)	(0.777)	(1.81)	(0.591)	(0.355)	(1.135)
22	0.188	0.194	0.612	0.085	0.129	0.23	0.248	0.21	0.727	0.057	0.04	0.213
	(0.694)	(0.672)	(1.346)	(0.406)	(0.557)	(0.81)	(0.73)	(0.678)	(1.23)	(0.322)	(0.23)	(0.648)
23–24	0.731	0.77	1.852	0.303	0.264	0.648	0.634	0.638	1.852	0.363	0.19	1.025
	(1.524)	(1.44)	(2.679)	(1.114)	(0.932)	(1.754)	(1.148)	(1.344)	(2.365)	(0.871)	(0.531)	(1.728)
25	0.539	0.471	0.833	0.296	0.269	0.402	0.739	0.749	1.494	0.203	0.156	0.46
	(1.552)	(1.238)	(1.556)	(1.1)	(0.913)	(1.07)	(1.222)	(1.55)	(1.745)	(0.553)	(0.448)	(0.887)
27,28	0.212	0.244	0.686	0.165	0.171	0.331	0.431	0.349	1.109	0.196	0.133	0.408
	(0.733)	(0.693)	(1.32)	(0.551)	(0.691)	(1.102)	(0.944)	(0.852)	(1.58)	(0.486)	(0.396)	(0.866)
29	0.23	0.223	0.935	0.112	0.171	0.405	0.361	0.374	1.368	0.144	0.133	0.586
	(0.706)	(0.641)	(1.731)	(0.671)	(0.674)	(1.215)	(0.91)	(0.941)	(2.105)	(0.546)	(0.375)	(1.049)

Table 6. (*Continued*)

	Collaboration with firms within the holding (internal collaboration)			Collaboration with competitors (horizontal collaboration)			Collaboration with suppliers and customers (vertical collaboration)			Collaboration with consultancies, universities, and other research institutes (knowledge collaboration)		
	Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)		
Industry	1996	2000	2004	1996	2000	2004	1996	2000	2004	1996	2000	2004
30–33	0.462	0.339	1.178	0.185	0.198	0.62	0.613	0.692	2.097	0.254	0.212	0.882
	(1.42)	(0.86)	(1.828)	(0.755)	(0.791)	(1.655)	(1.129)	(1.455)	(2.542)	(0.664)	(0.461)	(1.511)
34–35	0.419	0.473	0.856	0.29	0.37	0.548	0.532	0.504	1.541	0.28	0.165	0.594
	(1.09)	(0.883)	(1.571)	(0.752)	(1.149)	(1.73)	(1.085)	(1.116)	(2.015)	(0.67)	(0.382)	(1.246)
26, 36, 37	0.396	0.161	0.896	0.22	0.115	0.495	0.346	0.339	1.415	0.172	0.075	0.55
	(1.018)	(0.567)	(1.55)	(0.662)	(0.507)	(1.398)	(0.791)	(0.751)	(2.056)	(0.44)	(0.234)	(1.022)
45	0.164	0.252	0.602	0.193	0.296	0.586	0.2	0.333	0.795	0.131	0.12	0.463
	(0.6)	(0.825)	(1.208)	(0.638)	(0.694)	(1.232)	(0.564)	(0.686)	(1.164)	(0.427)	(0.384)	(0.933)
51	0.438	0.472	0.806	0.24	0.269	0.508	0.406	0.395	0.974	0.127	0.116	0.431
	(1.087)	(1.279)	(1.654)	(0.857)	(0.978)	(1.501)	(0.96)	(1.069)	(1.668)	(0.475)	(0.444)	(1.033)
50, 52	0.31	0.173	0.706	0.207	0.183	0.403	0.247	0.275	0.766	0.079	0.065	0.215
	(0.821)	(0.624)	(1.446)	(0.679)	(0.553)	(0.977)	(0.684)	(0.691)	(1.042)	(0.315)	(0.282)	(0.581)
60–64	0.23	0.417	0.528	0.18	0.365	0.528	0.275	0.465	0.903	0.104	0.153	0.329
	(0.712)	(1.071)	(1.423)	(0.726)	(0.949)	(1.447)	(0.669)	(1.193)	(1.613)	(0.378)	(0.423)	(0.874)
72	0.515	0.424	0.762	0.257	0.161	0.371	0.545	0.358	0.908	0.231	0.117	0.247
	(1.404)	(1.27)	(1.973)	(0.673)	(0.542)	(1.045)	(1.179)	(0.998)	(1.867)	(0.683)	(0.424)	(0.631)

Table 6. (*Continued*)

	Collaboration with firms within the holding (internal collaboration)			Collaboration with competitors (horizontal collaboration)			Collaboration with suppliers and customers (vertical collaboration)			Collaboration with consultancies, universities, and other research institutes (knowledge collaboration)		
	Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)		
Industry	1996	2000	2004	1996	2000	2004	1996	2000	2004	1996	2000	2004
65–67, 70, 71, 73, 74	0.382 (1.049)	0.227 (0.719)	0.568 (1.364)	0.302 (0.81)	0.295 (0.78)	0.429 (1.155)	0.364 (0.798)	0.307 (0.726)	0.773 (1.36)	0.204 (0.541)	0.132 (0.394)	0.402 (0.986)
55, 75–85, 90–99	0.236 (0.821)	0.238 (0.691)	0.202 (0.686)	0.142 (0.574)	0.079 (0.573)	0.484 (1.184)	0.197 (0.535)	0.188 (0.569)	0.343 (0.882)	0.068 (0.263)	0.069 (0.288)	0.202 (0.578)
Total	0.356 (1.019)	0.335 (0.962)	0.822 (1.654)	0.221 (0.767)	0.229 (0.773)	0.464 (1.307)	0.399 (0.925)	0.388 (0.971)	1.125 (1.762)	0.171 (0.526)	0.126 (0.395)	0.486 (1.055)

Table 7. Evolution of external and internal collaboration; scores are standardized between 0 and 10; only firms present in all three waves ($N = 397$).

	Collaboration with firms within the holding (internal collaboration)			Collaboration with competitors (horizontal collaboration)			Collaboration with suppliers or customers (vertical collaboration)			Collaboration with consultancies, universities, other research inst.		
	Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)		
	1996	2000	2004	1996	2000	2004	1996	2000	2004	1996	2000	2004
Food and Textile	0.632 (1.149)	0.526 (1.232)	**1.316**** (1.905)	0.368 (1.125)	0.175 (0.518)	0.395 (1.485)	0.868 (1.51)	0.417 (0.861)	**1.776***** (1.898)	0.439 (0.971)	0.274 (0.583)	**1.096***** (1.399)
Wood and Paper	0.846 (1.515)	0.449 (0.754)	**1.827***** (1.944)	0.231 (0.863)	0.128 (0.453)	**0.673**** (1.334)	1.077 (1.695)	**0.481*** (0.674)	**1.923***** (1.776)	0.359 (0.805)	0.192 (0.429)	**0.769**** (1.268)
Fossil fuels and chemicals	1.429 (1.852)	1.429 (1.945)	**2.714**** (3.054)	0.286 (0.86)	0.19 (0.883)	**0.714*** (1.554)	0.971 (1.361)	0.952 (1.402)	**2.5***** (2.59)	0.59 (1.057)	0.357 (0.777)	**1.262**** (1.889)
Rubber and plastic products	0.6 (1.314)	0.667 (1.134)	**1.5*** (1.885)	0.4 (0.821)	0.333 (1.026)	0.75 (1.428)	0.7 (1.455)	1 (1.613)	**2.25**** (2.316)	0.1 (0.326)	0.125 (0.385)	**0.667**** (1.068)
Metals and metal products	0.318 (0.74)	0.417 (0.73)	**0.966**** (1.637)	0.136 (0.51)	0.189 (0.645)	0.455 (1.114)	0.455 (0.791)	0.492 (1.196)	**1.222***** (1.439)	0.333 (0.528)	0.199 (0.397)	**0.511**** (0.847)
Machinery	0.444 (1.035)	0.185 (0.53)	**1.667***** (2.384)	0.089 (0.417)	0.222 (1.042)	0.611 (1.522)	0.511 (0.944)	0.481 (1.359)	**2.194***** (2.694)	0.326 (1.031)	0.176 (0.558)	**0.852***** (1.262)
Electrical and optical equipment	1 (2.024)	0.606 (1.097)	1.477 (2.745)	0.455 (1.371)	0.303 (0.658)	1.136 (2.642)	0.864 (1.167)	0.985 (1.679)	**2.443**** (2.95)	0.515 (0.74)	0.53 (0.658)	**1.553**** (1.912)
Transport equipment	0.375 (0.806)	0.729 (1.212)	1.25 (1.581)	0.25 (0.683)	0.521 (1.691)	0.781 (1.505)	0.438 (1.209)	0.625 (1.344)	**1.797*** (2.139)	0.583 (1.262)	0.234 (0.48)	0.573 (1.317)

Table 7. (*Continued*)

	Collaboration with firms within the holding (internal collaboration)			Collaboration with competitors (horizontal collaboration)			Collaboration with suppliers or customers (vertical collaboration)			Collaboration with consultancies, universities, other research inst.		
	Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)			Mean (Std Dev)		
	1996	2000	2004	1996	2000	2004	1996	2000	2004	1996	2000	2004
Other manufacturing activities	0.56	0.58	**1.4*****	0.24	**0.527***	0.9	0.68	**0.28***	**1.7****	0.427	0.378	**0.767****
	(1.227)	(0.246)	(1.78)	(0.663)	(0.208)	(2.151)	(0.988)	(0.249)	(2.1)	(0.635)	(0.208)	(1.126)
Construction	0.706	0.196	**0.882****	0.706	0.294	0.882	0.647	0.392	**1.324****	0.471	0.172	**0.637***
	(1.213)	(0.554)	(1.231)	(1.213)	(0.655)	(1.516)	(1.057)	(0.667)	(1.561)	(0.737)	(0.49)	(0.91)
Services	0.495	0.627	**1.193****	0.33	0.55	0.826	0.55	0.436	**1.376*****	0.202	0.218	**0.688*****
	(1.127)	(1.501)	(2.246)	(0.794)	(1.18)	(2.043)	(1.05)	(0.846)	(2.034)	(0.548)	(0.602)	(1.327)
Total	0.63	0.567	**1.442*****	0.292	0.323	**0.718*****	0.67	0.575	**1.763*****	0.351	**0.237****	**0.827*****
	(1.286)	(1.234)	(2.194)	(0.838)	(0.955)	(1.737)	(1.18)	(1.137)	(2.172)	(0.785)	(0.555)	(1.351)

*, ** and *** denote significant differences from the previous wave at the level of 10%, 5% and 1% respectively.

Table 8. Results GLM test for restricted dataset (restricted dataset).

The GLM Procedure: Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects: H0, no effect

	Source	DF	Type III SS	Mean Square	F Value	Pr > F
Degree of internal collaboration	time	2	67.033	33.517	18.1	<**0.0001**
	time*sbi2	2	2.962	1.481	0.8	0.4498
	Error(time)	790	1463.11	1.852		
Degree of horizontal collaboration	time	2	8.241	4.121	3.07	**0.0469**
	time*sbi2	2	4.545	2.273	1.69	0.1845
	Error(time)	790	1060.034	1.342		
Degree of vertical collaboration	time	2	104.4	52.2	26.9	<**0.0001**
	time*sbi2	2	3.434	1.717	0.88	0.4132
	Error(time)	790	1532.887	1.94		
Degree of knowledge collaboration	time	2	26.174	13.087	21.7	<**0.0001**
	time*sbi2	2	1.182	0.591	0.98	0.3759
	Error(time)	790	476.332	0.603		

Discussion of main findings

In his notable book, Chesbrough (2003a) argued that firms are switching from a closed to an open innovation model in which firms increasingly rely on external sources of information and/or collaboration with external partners to support their innovation activities. To our knowledge, this study is among the first to provide longitudinal data that provide quantitative evidence for this paradigm shift. Our data convincingly show that there is a positive trend in the extent to which organizations (1) apply knowledge that originated outside their boundaries, and (2) engage in formal collaboration with external partners for innovation purposes.

At the same time, though, our data seem to suggest that this trend towards open innovation is not a continuous trend but rather a change process that manifest itself by means of shocks. Moreover, we observed that the timing of these shocks might differ between industries. In the construction industry, for instance, a positive shock concerning the reliance on external sources of information was observed between the first and the second wave, while no significant differences were observed between the second and the third wave. In contrast, in the chemicals industry we did not observe significant changes between the first and second wave regarding the reliance on external sources of information. For this latter industry, the positive shock only manifested itself between the second and third wave.

According to Chesbrough (2003a), external innovation strategies should not be seen as a substitute for internal innovation strategies. In a similar vein, Cohen and Levinthal (1990) argued that firms can only take advantage of external knowledge

if they possess sufficient internal absorptive capacity. In sum, these scholars stress that external and internal innovation strategies should not be seen as substitutes. Our data support these arguments. We did not found instances where an increased reliance on external sources of information triggered a significant decrease in the reliance on internal sources of information. In addition, we observed that significant increases in the degree of collaboration with external partners were accompanied by significant increases in the degree of collaboration with internal partners.

Limitation and future research

In this study, we could only conduct T-tests for the firms that were present in all different waves. In this restricted dataset of 397 firms, large established firms are overrepresented though. This implies that our results might be biased for entrepreneurial small firms. Additional studies that focus on the evolution of open innovation in the particular setting of small firms is therefore necessary (Chesbrough *et al.*, 2006).

Chesbrough (2003a) argues that open innovation is not only about inflows of knowledge but also about outflows of knowledge. Although we managed to develop an adequate measure to represent knowledge inflows (i.e. reliance on external sources of innovation), the CIS surveys do not provide information that allows developing a measure for the knowledge outflows. We therefore encourage scholars to explicitly measure outflows of knowledge in future survey studies on open innovation.

Because of the construction of the CIS surveys, we did not have information about the evolution of external and internal innovation strategies between 1996 and 1998 and between 2000 and 2002. These gaps in our longitudinal design limited our ability to identify the exact timing of shocks in (1) the reliance of external sources of information and/or (2) the degree of collaboration with internal and external partners. Future research should therefore aim to develop longitudinal designs in which such gaps remain absent.

Acknowledgements

Useful comments and suggestions on this paper have been provided by editor Joe Tidd and the anonymous reviewers. An earlier version of this paper has been presented at the 1st ISPIM Innovation Symposium, Singapore, December 14–17, 2008.

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