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Innovation spells in the multinational agri-food sector

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Abstract

This paper examines the innovative history of a number of multinational agri-food companies using a database for utility patents and design patents. The first hypothesis to be tested is whether firms that innovate, usually do it persistently. We analyse a sample of 16,698 patents granted in the US over the period 1977–1994 to 103 F&B firms selected from the world's largest food and beverage multinationals (FBMs). The main conclusion that stems from these series is that only a small number of spells last for more than 4 yr. That is, only 6% of all utility patenting spells are ongoing after 4 yr, and only 1.6% of all design patenting spells are ongoing after 4 yr. Nevertheless, it is significant that there are 22 utility patents spells of the longest duration (18 yr). This frequency is only comparable to 3 yr long spells in utility patents and it is completely different from the design patents (there is only one 18 yr spell). However, this myriad of short-term projects coexist with long-run innovation. There is a small nucleus of persistent patentors who contribute around 80% of the total number of patents granted to the multinational agri-food sector. Persistent patentors are also heavy patentors since length of spells and average number of patents per year are statistically associated. Length of innovative spells is not associated, by contrast, with size of the company or specific agri-food subsector. Companies remaining innovative in the technical field tend also to remain innovative in design for long periods of time.

Keywords: Innovation; Design; Food and drink multinationals; Food and drink industry; Patents; Technological leadership

1. Introduction

Since the 1980s, experts in R&D management claim that innovative strategies should be suited to the characteristics of the industry in which the firm is active (Nieto, 2002). Insisting on the importance of continuous improvement at the company level, their views have evolved since the 1990s to become more dynamic. Understanding technological trends at the sector level is considered important because the successful firm adapts its innovation strategy to the phase of the product cycle and the temporal dynamics of technological production in the industry (Larue de Tournemine, 1991; Utterback and Suárez, 1993).

The knowledge of trends could be particularly useful when a nucleus of companies influence technological developments in a whole international industry for a long period of time, as is the case of giant food and beverage multinationals (FBMs). The world's largest FBMs patent more than 50% of the world's innovations produced in food and tobacco (Alfranca et al., 2002; Patel and Pavitt, 1991) and display a strong capacity for directing innovation processes in the sector (Anon, 1979).[1] They have headed the development of food and food-related technology worldwide and have used their superior knowledge to maintain barriers to entry and mobility over long periods of time.

However, we know little about the innovators' profiles in this multinational industry and the period of time over which they remain innovative. The temporal dynamics are not the same in industries technologically dominated by numerous new entrants searching for well-adapted designs of a new product as compared with those where a few established companies control the production of technology (Utterback and Suárez, 1993), as is the case of the food and drink industry. Illustrating the first case, Clark observes that the pattern of production of innovation during the early phases of the automobile industry

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[1] In addition, according to Rastoin et al. (1998), the world's 100 largest multinationals account for 38% of the production value of the international F&B industry.

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(1985–1940) was characterized by bursts of innovation and then long periods of no innovation, followed again by new bursts of innovation. The rhythm and sequence of innovations among the giant companies which dominate the technological arena in the food and drink industry have seldom attracted the attention of researchers, who tend to be much more interested in turbulent markets of high-technology products where innovations are often introduced instead by small new entrants.

This article contributes to filling this gap and focuses on the temporal pattern of innovation in large firms of a traditional sector where innovation is incremental (Christensen et al., 1996; Galizzi and Venturini, 1996). In doing so, we try to develop a better understanding of the nature of cumulative processes. We study the technological history of the world's largest food and beverage multinationals (FBMs) in order to analyse for how long such firms remain innovative, identifying both occasional and persistent innovators. We analyse patent spells, i.e. periods of time during which the company innovates year after year without gaps in its activity (Geroski et al., 1997).

While we search for general trends in the sector, we are also interested in differences among firms. In spite of the importance of FBMs in food and food-related technology, a longitudinal analysis of their patterns of innovation over long periods of time shows that many are not continually innovative (Alfranca et al., 2002). Even some companies in the top group, i.e. among the world's 100 largest FBMs, innovated only sporadically over the last period.[2] A detailed analysis of the innovative behaviour of the companies, like that undertaken in this article, is therefore necessary to understand technological trends in the multinational agri-food industry.

In section 2 we discuss the relationship between persistence and technological leadership in order to show why continuous innovation is relevant to the firm. In section 3 we present the data that will be analysed in this article, a sample of 16,698 utility and design[3] patents granted to the world's largest FBMs in the US over 1977–94. In section 4 we present the hypotheses to be tested and the theoretical background that informs the research. In section 5 we identify the heaviest patentors in the multinational agri-food sector. Then, we examine time-series of patents granted to the firms in our sample and calculate for how many years FBMs remain innovative, in both the technical and design fields. We try to find patterns of behaviour among the most important patentors in the multinational agri-food sector: steady flows of innovation over long periods of time or short bursts of innovation during which companies patent a great number of inventions, followed by periods with no innovation? We test whether the length of innovative spells is associated with specific characteristics of the company. We also test whether firms that remain innovative for long periods of time in the area of technical innovation also remain innovative in design, or if instead there is a trade-off between both innovative models. Finally, in section 6, we provide our conclusions.

2. Persistent innovation is an ingredient of long-term technological leadership

There is an increasing consensus about the dynamic character of technological leadership. Though, in theory, Schumpeterian entrepreneurs enjoy (temporary) monopoly advantages because they are first to the market, in practice many pioneers fail to collect all the fruits of their efforts. This recognized fact induced researchers to examine other angles of technological leadership in addition to being a pioneer. The time perspective was especially taken into consideration since 'it is relatively simple to succeed once with a lucky combination of new ideas and receptive market at the right time—but it is quite another thing to repeat the performance consistently' (Tidd et al., 1997, p. 37). Using a historical method to study 50 consumer product categories including food, Tellis and Golder (1996) conclude that, in their sample, innovative *persistence* rather than order of entry explains the success of the companies. The authors believe that long-term leadership requires continuous innovation. On the other hand, when a firm launches new products, it is more likely to be successful, they claim, if consumers can easily recognize the manufacturer. *Brand names* that consumers recognize easily are an asset for innovative companies.[4] Hence the importance of constant innovative activities in food packaging designs as well. Thus, trends in design innovation will be analysed here together with the pattern of technical innovation. Other authors point to the *dynamic capabilities* (Teece et al., 1997) that enable firms to utilize knowledge over long periods of time for continuing competitive advantage (Helfat and Raubitschek, 2000).

Previous research suggests that persistent innovators learn more easily, research more effectively and obtain a constant feedback from their past innovative experience.

[2] For instance, companies such as Archer Daniels Midland Co., Associated British Foods, Koninklijke Wessanen, Molson Co. or Union Laitière Normande obtained less than two utility patents in the US between 1977 and 1994 (Alfranca et al., 2001).

[3] We use the term design in a more restricted meaning than before, since now we refer exclusively to packaging aesthetics in foodstuffs, not to engineering design.

[4] In 1961, they recall, Royal Crown redirected successfully diet cola from a limited market for diabetics to the mass market. However, it was Diet Coke which finally captured the mass market at the beginning of the 1980s because the consumer could more easily recognize the Coca-Cola brand name. As we will see later, in the top group, Coca-Cola is among the most persistent innovators in the design field.

Without continuous learning, acquired skills decline and interruptions could lead to their atrophy (Lazonick and West, 1998); some authors even speak of a 'forgetting curve' (Maskell, 2001). Moreover, whatever the amount of investment devoted to innovative activities, programmes developed over a period of time are more effective than 'crash' R&D programmes (Dierickx and Cool, 1989). In a study based on patents belonging to 33 technological categories which were granted in 1969-86 to firms from five European countries, Malerba et al. (1997) find that persistence of innovation is associated with good technological performance as measured by two different indicators: innovative intensity and revealed technological advantage. Finally, in FBMs, past innovation affects positively the current production of both technical and design innovation (Alfranca et al., 2002). Much more influential than exogenous stimuli, such as regulatory or market changes, which have only ephemeral effects on the patenting activity of the firm, past innovation strongly affects current innovation in the first four years after a patent is granted to an FBM. Even afterwards, it continues exerting a favourable though much weaker effect for long periods of time.

Thanks to continuous improvements of its products, the persistently innovative firm can even benefit from better economic performance than non-innovators or occasional innovators because such improvements help it to keep customers over the long run. Even small and unpatented ameliorations enhance the company's ability to launch new products continuously and, hence, to perform well (Connor, 1981). In addition, given that consumers frequently tire of old designs, persistent designers periodically renew their packaging as a tool against competitors (Telser, 1961; Brown and Lee, 1999). In some industries, firms are persistently profitable only when innovation is repeated (Roberts, 1999). Thus, FBMs that are involved, without gaps, in R&D and design activities for long periods of time are probably better able to deter entry and mobility of rivals than occasional innovators who, by contrast, are less likely to maintain the advantages derived from their new foodstuffs, processes and designs.

3. Theoretical background and hypotheses

This section presents the theoretical background that informs this research and the hypotheses to be tested.

3.1. Who introduces innovations in the multinational agri-food sector?

Recent research tends to demonstrate that persistent innovative behaviour is technology or sector specific (Breschi et al., 2000; Cefis and Orsenigo, 2001; Malerba et al., 1997). Irrespectively of the country where the company is based, the same sectors are characterized by similar temporal patterns of innovation. In most sectors, however, innovative activities display a high level of turbulence and the population of innovators changes significantly over time. Though some of the above-mentioned cross-sectional studies include food, their results are, however, inconclusive regarding the particularities of the sector.

Based on the preceding discussion, we identify who introduces the bulk of patented inventions in the multinational agri-food industry: companies highly innovative over short periods of time or long-run innovators.

3.2. How long do firms remain innovative?

Using both patent and innovation data, Geroski et al. (1997) study the history of a large group of British firms and find that only a small number of them remain innovative over long periods of time. Analysing a sample of FBMs similar to that utilized in this paper, Alfranca et al. (2002) observe that past innovation strongly influences innovation for periods of four years, after which the effect becomes more diluted. This finding suggests that spells are short in the multinational agri-food sector.

Hence, we test for how long FBMs remain innovative in both the technical and design fields by studying the length of spells.

3.3. Timing and volume of innovative activities

Cross-sectional studies point to the association of timing and volume of innovative activities. Geroski et al. (1997) notice the association of spell lengths and the initial level of patenting in the company. More interestingly, they detect a non-linear association: only relatively high thresholds of previous accumulative knowledge trigger long periods of innovative activity. Malerba et al. (1997) find that the final stock of patents per firm at the end of the period is statistically associated with the persistence of innovation among the European companies in their sample.

The association of timing and volume of innovative activities is related to the already mentioned issue about whether 'old' or 'new' innovators introduce innovations in an industry. In some high-tech industries, it is the latter who are the chief contributors of innovations. However, they are likely to remain intensively active only for short periods of time and are quickly substituted. In turn, the new wave of new entrants keeps innovating also for short periods. In such industries, innovation is sequential rather than synchronous (Niosi, 2000); the volume of patents and the length of innovative spells could be negatively associated because each innovator introduces a great deal of innovations over a short period of time only. In the multinational agri-food sector the situation seems to differ. With a similar sample to that utilized in this paper, Alfranca et al. (2002) show that, in this sector, innovations are introduced by ‘old’ innovators who had also been granted patents in the previous few years, not by ‘new’ innovators. Taking now a longer-term view of the question, we expect that most patents in the sector will be granted to innovators who remain active for many years. Thus, we expect a statistical association between the volume of patents granted to a company and the period over which it stays innovative.

In the light of such theory, we test whether the maximum length of spells over 1977–94 is statistically associated, at the company level, with the annual number of patents per firm over the same period. As we have said, we expect the two to be associated. We test this hypothesis in both technical and design fields.

3.4. Persistence of innovation and characteristics of the firm

The literature is discrepant about the association of persistence in innovation and size of the company. Geroski et al. (1997) reach the conclusion that ‘persistent innovation is not strongly linked to firm size, although there does seem to be a positive relation between the length of the innovation spells and firm size’. By contrast, in their analysis of 525 innovative Spanish firms studied over 1984–94, Molero and Buesa (1998) find that those who undertake R&D projects more regularly are likely to be large (controlling for exports, technological opportunity, R&D intensity and other variables). Among French, German, Japanese, UK and US companies belonging to chemical, mechanical engineering, and electric and electronics machinery, Cefis and Orsenigo (2001) also observe the positive association between size and the persistence in innovative activities.

Here, we test whether the maximum length of spells over 1977–94 is related to the average size of the company, as measured by average annual sales over the period. Do large FBMs tend to remain innovative for longer periods of time than smaller firms? As before, we study this question in both the technical and design fields.

As already mentioned, temporal patterns of innovation seem to be sector-specific. Thus, persistence in innovation could be a characteristic of some industries and not others. Cefis and Orsenigo (2001) observe different patterns among different industries. Molero and Buesa (1998) also find different innovative models among Spanish firms belonging to different sectors and conclude that companies engaging more regularly in R&D are likely to belong to industries showing more technological opportunities. Previous research, however, tests for the association between innovative persistence and sector at the 2-digit level, not within-industries. Here, we test if spell length depends on the type of agri-food sector (agribusiness and basic food, highly processed food, and beverages) to which the firm belongs. Again, we test this question in both the technical (utility) and design fields.

3.5. Technical and design innovation

Using a similar sample of companies and patent data to that utilized here, we found that technical and design innovations were associated in the multinational agri-food sector, contrary to the popular perception that F&B companies use cosmetic modifications to mask the absence of intrinsic innovation (Alfranca et al., accepted). Based on these findings, we test whether firms who remain innovative for long periods of time as regards technical innovation also remain innovative as regards design innovation. We expect that long trends in technical innovation are associated with long trends in design.

4. The data

We combine information from two databases: a patent database and a database containing economic information, such as global sales and type of business, on the world’s 100 largest FBMs. The resulting database comprises 16,698 patents granted in the US, over the period 1977–94, to 103 firms selected from the world’s 100 largest FBMs.

Our sample actually includes 103 companies because of the entries and exits in the top group during 1977–94. The FBMs in our sample belong to a variety of industries, such as confectionery, dairy products, wine and spirits, grain milling, etc. All are food or beverage processors and a number of them also hold agribusinesses, retail concerns, etc. (for an analysis of industrial diversification in FBMs, see Anastassopoulos and Rama, 2003, in press).

All companies have patented at least one invention over the period. Given the importance of marketing in this industry, we study not only their utility patents, which protect technical inventions, but also their design patents, which protect innovation in packaging aesthetics.[5]

Firms were selected from AGRODATA (Padilla et al., 1983; I.A.M.M., 1990; Rastoin et al., 1998), a database produced by the Institut Agronomique Méditerranéen de Montpellier (France). The I.A.M.M. has been collecting information on the world’s 100 largest FBMs since the

[5] According to the US Patent and Trademark Office a design patent protects ‘only the appearance of the article and not its structural or utilitarian features’. While a utility patent protects ‘the way an article is used and works’, a design patent protects the way it looks. The USPTO web page explains that minimal differences between similar designs can render each patentable.

1970s.[6] The database provides information on the global sales of the firms and their UN-SIC (four-digit Standard Industrial Classification) classes, which we use to classify companies into the three different types of business previously noted: agribusiness as well as basic food, highly processed food, and beverages.

We measure innovation by using patent data.[7] In spite of some drawbacks (Archibugi and Pianta, 1996; Rosenberg, 1982), patents are a good indicator of technological production at the company level because firms use patents as legal protection for their most valuable innovations. Patent statistics provide a ‘unique long-term time series of inventive efforts on a worldwide basis’ (Freeman, 1994, p. 476). Moreover, a number of empirical studies support the idea that patents reflect with some accuracy other manifestations of technological change, such as innovative activities and R&D expenditures at the firm level (Acs and Audretsch, 1989; Bound et al., 1984). Finally, in their study on the length of innovative spells, Geroski et al. (1997) find that, among British firms, the distribution of patents is similar to that of commercially successful and technologically important innovations.

Table 1
Characteristics of the sample

Company distribution	% of firms
Agribusiness and basic food	26.2
Highly processed food	57.3
Beverages	16.5
Patent distribution	**% of patents**
Type of patent	
Utility patents	88.7
Design patents	11.3
Home-country of the patentor	
Western Europe[a]	43.1
US	31.2
Canada	6.4
Japan	19.3

[a] Includes France, Great Britain, the Netherlands and Switzerland.

Patents are particularly suited to studying innovative spells such as those analysed in this paper because technicians and R&D departments perceive patents as an objective indication of success. Since managers are often concerned with reducing cycle-time in R&D and with balancing long and short-term R&D objectives,[8] continuous streams of patents are probably seen as a success by the organization as well. The self-perception of success through a clear benchmark, like a patent, could affect the duration of learning processes. Companies that perceive themselves as successful in their innovative efforts are more likely to set higher aspirations and persist in overt learning over longer periods of time (Winter, 2000). Thus, not only can the economist use patents to measure for how long a company remains innovative, as we do in this paper, in addition the company can use patents to assess its own success at learning and thus persistence in innovating, or alternatively adjust downward its own expectations.

The variable used here is the number of patented innovations granted in the US from 1977 to 1994, totalling 16,698 patents.[9] Foreign patenting in *one* particular country is often used in international analyses of innovation (Fagerberg, 1987). Patenting in the US probably reflects accurately the world’s stock of technology, as shown by Soete’s (1987) results. It is unfortunately not easily possible to distinguish process from product patents from the US classification system, short of detailed scrutiny of each patent specification, which for the number of patents covered here is beyond our means.[10] The patents classified are all patents registered for the companies in our sample and their affiliates over the period specified. They consider a variety of technological fields

[6] Its sources are Moody’s Industrial Manual, the Fortune Directory of the 500 largest US and the 500 largest non-US corporations, the ‘Dossier 5.000’ of the largest European companies published by *Le Nouvel Economiste*, Dun & Bradstreet and the annual reports of the enterprises, among others. To be included in the database, the firms must meet several criteria: (1) their annual agri-food sales must be US$ 1 billion, at least; (2) their sales of processed food and beverages must be more than 50% of their total sales; and (3) they must have at least one foreign affiliate. By the mid-1990s, 151 firms met these criteria. The 100 largest, according to their sales value, were included in AGRODATA.

[7] In this article we focus on innovations *produced* by F&B companies. This industry also *uses* innovations produced by manufacturers in other sectors (Rama, 1996).

[8] ‘Biggest’ problems technology leaders face’. *Research-Technology Management* 1995, 38(5), 13.

[9] The data are taken from the numbers of patents granted at the US Patent Office (USPTO). The data from 1975 onwards (only) are nowadays available online from the USPTO (http://www.uspto.gov). However, working the data from online sources or CD-ROM into usable results still involves intensive research efforts. Basically the USPTO assignees are given according to the name of the organization to which they are directly affiliated, rather than the name of the corporation. A large patenting firm such as Unilever or Philip Morris may have hundreds of these patenting subunits in addition to the core corporation, and the task of consolidating them into corporate totals is a major one, since the USPTO database does not record their ownership. The latter information has to be painstakingly constructed from sources such as *Who Owns Whom?*, before searching the database and then aggregation.

[10] There are two reasons for this. The first is that the US classification mixes product and process patents at the three-digit level, as the titles of the classes indeed indicate (see note 11 below, for the major case of class 426). The second is the inherent technical difficulty of deciding whether a particular patent refers to a product or a process innovation, e.g. for many F&B patents in the area of ingredients or chemicals—within one and the same company it may well happen that a product innovation is developed at one site to be used as a process innovation on another site (and so on).

Table 2
Name, description and sources of the variables

Name	Description	Source
SIZE	Global average annual sales over 1977–94 in 1990 PPP prices[a]	AGRODATA, OECD
INDUSTRY	Sector in which the company markets most of its sales. Three categories[b]	AGRODATA
UTILITY	Average annual no. of utility patents granted to the company over 1977–94[a]	SPRU
DESIGN	Average annual no. of design patents granted to the company over 1977–94[c]	SPRU
SPELLUT	Maximum average length of innovative spells (utility) by company over 1977–94[a]	SPRU
SPELLDES	Maximum average length of innovative spells (design) by company over 1977–94[d]	SPRU

[a] Categorized into seven categories for statistical analysis.
[b] Agribusiness/basic food; highly processed food, and beverages.
[c] Categorized into 4 categories for statistical analysis.
[d] Categorized into 5 categories for statistical analysis.

such as food proper, biotechnology, tobacco and also innovations related to non-core businesses of the companies.[11] The characteristics of the sample are displayed in Table 1. The description and sources of the variables analysed in this paper are given in Table 2.

5. Empirical analysis

5.1. How long do FBMs remain innovative?

First, we analyse the descriptive statistics and the frequency of the patent data. On average, FBMs patent more utility than design innovations, though measures of dispersion suggest greater variability of the utility variable. FBMs patented annually around nine utility patents (Md = 2; SD = 22.5) and nearly two design patents each (Md = 1; SD = 3.1) over the period. The Jarque–Bera normal statistic indicates that both utility patents (0.917) and design patents (0.083) follow a log-normal distribution.

Most FBMs contribute individually only a small share to the pool of patents in the multinational agri-food sector. Table 3 displays the frequencies of both utility and design patents by company over 1977–94. Only 21 firms have relative frequencies higher than 1% of total utility patents, and a very similar number (22 firms) apply for design patents (Table 3). Only 14 companies contribute more than 1% each to both the pools of utility and design patents: Borden Inc, C.P.C. International, Coca Cola Co., Con Agra Inc, General Mills Inc, Ito Ham Foods Inc, Mars Inc, Nestlé, PepsiCo Inc, Philip Morris Co. Inc, Procter and Gamble Co., RJR Nabisco Inc, Sara Lee Corporation, Unilever. As will be seen later, some of these heavy patentors are also persistent patentors who innovate continuously over long periods of time.

Now we analyse for how many years FBMs remain innovative. We calculate the patenting spells, i.e. the number of successive years in which a firm produces at least one patent per year (Geroski et al., 1997). As above-mentioned, we define patent spells as periods of time during which the company innovates year after year without gaps in its activity. We calculate such periods for both utility and design patents.

The 103 FBMs in the sample have 1015 spells between them in the utility patent series and 1573 spells in the design patent series.[12] Lengths of spells oscillate between 1 and 18 yr, the maximum length-patenting spell per firm[13] (Table 4). The main conclusion that stems from Table 4 is that only a small number of spells last for more than four years. That is, only 6% of all utility patenting spells are ongoing after four years, and only 1.6% of all design patenting spells. Nevertheless, it is significant that there are 22 utility patent spells of the biggest length (18 yr). This frequency is only comparable to 3-yr long spells in utility patents and it is completely different from the design patents (where there is only one 18 yr spell). Concerning utility patents, our results are quite similar to those of Geroski et al. (1997), who find that only 7% of spells are going on after four years.

5.2. Three regimes of patenting

From this, we identify three regimes of patenting behaviour: single patentors, who produce a few patents in a short spell; sporadic patentors, who produce a hand-

[11] 'Food' patents cover the three-digit classes of the USPTO as follows: 426 ('Food or edible material: processes, compositions and products'), 127 ('Sugar, starch and carbohydrates'), and 99 ('Food and beverages: apparatus'). Tobacco patents are from class 131. A full concordance with the 400-odd USPTO classification is too long to publish here but is available from Prof. von Tunzelmann on request.

[12] Some firms may have several spells. The variables SPELLUT and SPELLDES, as indicated in Table 2, take into consideration the longest one over 1977–94.

[13] We analyse the no. of patents granted to firms over 1977–94. The length of their maximum spells could be, thus, left or right censored. Some spells could actually start before 1977 and others could go on after 1994.

Table 3
Utility and design patents. Relative frequencies, by company (1977–94)

Firms	Utility patents	Design patents
Ajinomoto Co. Inc	2.56	0.51
Allied Lyons	0.31	0.70
American Brands. Inc	1.58	0.49
Anheuser Busch Co. Inc	0.46	0.57
Archer Daniels Midland Company	0.17	0.51
Arla	0.13	0.51
Associated British Foods plc	0.13	0.49
B.P. Nutrition Ltd	0.19	0.60
Barilla Spa	0.24	0.65
Barlow Rand Ltd	0.22	1.35
Bass plc	0.17	0.51
Beatrice Co. Inc	0.11	0.49
Besnier S.A.	0.13	0.49
Booker plc	0.15	0.49
Borden Inc	1.30	3.22
BSN Groupé	0.19	0.65
Bunge & Born Co	0.12	0.49
C.P.C. International	1.12	1.65
Cadbury Schweppes plc	0.34	0.65
Campbell Soup Co	0.73	0.65
Canada Packers Inc	0.52	0.49
Cargill Inc	0.62	0.49
Carlsberg a/s	0.15	0.54
Castle & Cooke Inc	0.31	0.49
Cie Financiere Sucres et Denrees	0.12	0.51
Coberco	0.35	0.49
Coca Cola Company	2.42	3.60
Conagra Inc	1.25	1.70
Dalgety plc	0.18	0.51
Dean Foods Co	0.16	0.76
Elders IXL Ltd	0.13	0.51
Ezaki Cuco Co. Ltd	0.12	0.49
Ferrero spa.	0.39	1.43
General Mills Inc	1.21	2.33
Geo Hormel & Co	0.26	0.57
George Weston Ltd	0.30	0.51
Goodman Fielder Wattie	0.14	3.60
Grand Metropolitan plc	1.04	0.60
Grupo Ferruzzi	0.19	1.65
Guinness plc	0.30	0.68
Guyomarc'h S.A.	0.14	2.33
H.J. Heinz Compnay	0.37	0.54
Hanson plc	0.22	0.49
Heineken n.v.	0.26	0.54
Hershey Foods Corp.	0.22	0.49
Hillsdown Holdings plc	0.11	0.51
House Food Industrial Co Ltd	0.63	0.51
Imasco Ltd	0.29	1.03
International Multifoods	0.25	4.65
Ito Ham Foods Inc	15.14	6.19
Jacobs Suchard S.A.	0.24	0.49
John Labatt	0.37	0.54
Kellogg Co	0.21	0.51
Kikkoman Corp	0.60	0.54
Koninklijke Wessanen n.v	0.15	0.49
Kyokuyo Co Ltd	0.16	0.51
Land o'Lakes Inc	0.21	1.16
LMH Moet Hennessy/Louis Vuitton	0.22	1.35
Mars Inc	1.06	0.95
McCormick & Co Ltd	0.22	0.57
MD Foods Amba	0.11	0.49

(*continued on next page*)

Table 3 (*continued*)

Firms	Utility patents	Design patents
Ajinomoto Co. Inc	2.56	0.51
Meiji Seika Kaisha	1.17	0.65
Melkunie Holland	0.14	0.51
Molson Companies Ltd	0.19	0.51
Morinaga Milk Industry	0.52	0.68
Nestlé	5.24	1.16
Nichirei Corp.	0.13	0.49
Nichiro Gyogyo Kaisha	0.12	0.51
Nippon Meat Packers Inc	0.15	0.49
Nippon Suisan Kaisha Ltd	0.25	0.51
Nisshin Flour Milling Co Ltd	0.83	0.49
Nissin Food Products Co Ltd	0.35	0.49
Pepsico Inc	1.54	1.03
Pernod Ricard	0.15	0.51
Philip Morris Companies Inc	9.54	4.65
Pillsbury Co	0.11	0.49
Procter and Gamble Company	12.78	5.27
Provendor Group	0.24	0.57
QP Corporation	0.30	0.49
Quaker Oats Company	0.11	0.49
Ralston Purina Co	1.51	0.95
Ranks Hovis McDougall plc	0.22	0.51
RJR Nabisco Inc	5.17	1.54
S&W Berisford Ltd	0.11	0.49
Sandoz a.g.	0.11	0.49
Sapporo Breweries Ltd	0.24	0.51
Sara Lee Corporation	1.31	1.70
Scottish & Newcastle Breweries plc.	0.15	0.49
Seagram Co Ltd	0.22	0.60
Snow Brand Milk Products Co	0.78	0.49
Source-Perrier	0.24	0.65
Suntory Ltd.	1.08	0.76
Tate & Lyle plc	1.62	0.51
Toyo Suisan Kaisha Ltd	0.17	0.49
Unigate plc	0.11	0.49
Unilever	10.53	3.22
Union International plc	0.11	0.49
Union Laitiere Normande	0.11	0.49
United Biscuits	0.19	0.49
United Brands Co	0.14	0.51
Whitbread & Co plc	0.14	0.70
Whitman (I.C. Industry)	0.11	0.49
Yamazaki Baking Co	0.12	0.49

Source: Author's calculations

ful of patents in an intermediate period of time; and finally persistent patentors, who generate a large number of patents for long periods of time (Table 5).[14] Cuts between the three categories were made according to the distribution of both utility and design innovative spells among the companies in our sample (histograms not displayed). The tables should be interpreted as follows. For instance, single patentors, i.e. companies whose longest innovative spell (utility) is four years, obtained on average 26 patents over 1977–94.

Some examples of persistent innovators in the technical (utility) field are Ito Ham Foods, a Japanese multinational, and three large conglomerates, Phillip Morris, Procter & Gamble, and Unilever. All are also persistent designers. Other examples of persistent designers are Coca-Cola, Borden Inc., Goodman Fielder Wattie, and International Multifoods.

As regards utility patents, the bulk of FBMs (53%) are single patentors (Table 5A); however, their contribution to the total number of patents is small (9%). By contrast, persistent patentors are only slightly more than

[14] Geroski et al. (1997) classify the firms in their sample as single, sporadic and heavy patentors according to the spell length in such companies.

Table 4
Distribution of patent spell lengths in agrifood multinational companies, by type of patent (1977–94)

	Utility patents		Design patents	
length[a]	No. of spells	%	No. of spells	%
1	882	86.90	1499	95.30
2	36	3.55	31	1.97
3	23	2.27	9	0.57
4	14	1.38	9	0.57
5	9	0.89	7	0.45
6	6	0.59	4	0.25
7	7	0.69	0	0.00
8	5	0.49	4	0.25
9	1	0.10	0	0.00
10	0	0.00	0	0.00
11	3	0.30	2	0.13
12	1	0.10	0	0.00
13	0	0.00	0	0.00
14	1	0.10	2	0.13
15	2	0.20	3	0.19
16	2	0.20	2	0.13
17	1	0.10	0	0.00
18	22	2.17	1	0.06
	1015		1573	

Source: Authors' calculations
[a] Number of years.

a fifth of the companies but they supply 81% of the utility patents granted to the multinational agri-food sector over 1977–94. Finally, occasional patentors with medium spells provide another small portion (10%) of the total number of utility patents granted to the world's largest FBMs over the period. Progress in technological achievement from one regime to the other is not steady. Instead, one observes jumps in the average number of patents granted to the firm over the period. The leap in the number of patents is especially evident between the categories of sporadic and persistent patentors (last line of Table 5A), suggesting that after a threshold,[15] i.e. a minimum period of time devoted to focussed R&D, the number of innovations snowballs, increasing at a rapidly accelerating pace.

However, in term of the number of patents, not all long-spellers (i.e. persistent patentors) are equally creative. The plot of SPELLUT versus UTILITY (not displayed) shows that the values of UTILITY are much less spread for smaller than for larger values of SPELLUT. In other words, the variance of the average number of annual patents is low among firms with short ($\sigma^2 = 0.21$) to medium spells ($\sigma^2 = 4.03$). By contrast, among long-spellers, the variance of annual patent production is very high ($\sigma^2 = 1596.69$).[16]

The panorama is rather different as regards design patents. Most of the FBMs (77%) are also single patentors who innovate in design, without interruptions, for very short periods of time (three or fewer years). However, unlike single patentors of utility patents, single patentors of design patents provide most of the design patents (44%) granted to the multinational agri-food sector (Table 5B). On the other hand, the longest design spells tend to be shorter than the longest utility spells, as shown by the classification of patentors based on the histogram of the two spell variables (SPELLUT and SPELLDES).[17] By contrast with technical innovation (utility), the volume of design patents does not tend to snowball but rather augments steadily, as the number of years devoted to uninterrupted innovation increases.

Multi-response cross tabulation shows that most companies (46%) are single patentors in both the technical and design fields. The other side of the coin is the group of FBMs (around 7% of total) who are, instead, persistently innovative in both areas. In this group, some examples are Sara Lee or Unilever.

Logically enough, in our sample of very large multinationals, the production of innovation is less concentrated than in the sample analysed by Geroski et al. (1997). For instance, they find that persistent innovators, who account for only 2% of the companies, produce around half the patents granted to British enterprises.

5.3. Length of spells and volume of patenting are associated

Now we explore whether the innovators who display longer spells tend to produce more patents per annum. Given that the distributions of SPELLUT and SPELLDES are not normal, we categorize these quantitative variables for statistical analysis.[18]

The relationship between high scores of average number of utility patents (UTILITY) and high scores of length in utility spells (SPELLUT) was tested with

[15] The plot of SPELLUT versus UTILITY suggests that the minimum period of continuous innovation needed for the 'take-off' of patent production is about 12_14 yr.

[16] Several reasons could explain such differences in creativity among long-spellers. In some cases, companies involved in R&D for long periods could be more interested in materialising their expertise in selling technical services, for instance, than in obtaining an enormous amount of patents. This is apparently the case of Tate & Lyle, which nearly doubles the average production of patents in the sector but still ranks far below other long-spellers, such as Ito Ham, with 135 patents granted per year. Through T&L Engineering, the company sells, instead, technical services and turnkey sugar mills (Oman et al., 1989). This example points to the limits of patent analyses as a measure of the technological progressiveness of companies.

[17] For descriptions of variables, see Table 2.

[18] We do not use the three regimes of patenting as categories for analysis. We prefer to break down SPELLUT and SPELLDES into the greatest number of categories, by deciles, to take full advantage of the quantitative information.

Table 5
Regimes of patenting behaviour in the multinational agri-food industry, 1977-94

	Single patentor	Sporadic patentor	Persistent patentor
A. *Utility patents*			
Maximum duration of spells per firm(no. of years)	≤ 4	5-16	≥ 17
% of firms	53	25	22
% of utility patents	9	10	81
Av no.of patents/firm[a]	26	65	565
B. *Design patents*			
Maximum duration of spells (per firm no. of years)	≤ 3	4-12	≥ 13
% of firms	77	15	8
% of design patents	44	24	32
Av.no. of patents/firm[a]	2	42	132

Source: Authors'calculations
[a] Average no. of patents per firm over 1977-94.

bivariate correlational techniques for ordered categories (Table 6). The rank order correlation coefficient (Spearman's ρ) was large and statistically significant.[19] Kendall's τ (b and c) confirmed the positive and highly significant association between the variables. Thus, the companies who remain active for many consecutive years without gaps tend to patent annually a great number of innovations. We find similar results when we analyse the relationship between the average number of design patents (DESIGN) and the length of design spells (SPELLDES) (Table 7). The rank order correlation coefficient is also large and Kendall's τ (b and c) also confirms the positive and highly significant association between the variables. In both tables, eta shows that each of the variables explains a large proportion of the variance of the other.

However, in both tables, direction tests (Somer's *d*) display higher coefficients when the number of patents (either UTILITY or DESIGN) is the dependent variable, which suggests that the length of the spells influences the annual production of patents rather than the presence of a symmetrical association between the variables.

5.4. Length of spells and characteristics of the company are not associated

Now we test the association between the length of utility spells (SPELLUT) and the size of the firm (SIZE) with bivariate correlational techniques. The latter is categorized as an ordinal variable for analysis. The rank order correlation coefficient is low, though statistically significant (Spearman's $\rho = 0.20$, sig. $=$ 0.05, Monte Carlo sig. $=$ 0.05; $N = 92$). However, Kendall's τ (b and c), which is a more reliable rank test, shows that the association between both variables is even weaker and not statistically significant (τ-b $= 0.14$, $P = 0.08$, Monte Carlo sig. $= 0.07$; τ-c $= 0.15$, $P = 0.08$, Monte Carlo sig. $= 0.07$). The association between the length of design patents (DESIGN) and the size of the company is positive, though very weak and statistically not significant (Spearman's $\rho = 10$, $P = 0.344$, Monte Carlo sig. $= 0.347$). This result is corroborated by Kendall's τ (b and c): τ-b $= 0.08$, $P = 0.389$, Monte Carlo sig. $= 0.334$; τ-c $= 0.08$, $P = 0.389$, Monte Carlo sig. $= 0.334$.

Our findings on the relationship between size and length of spells confirm Geroski et al. (1997) for British firms, since they also find no significant relation between persistence of innovative activities and size of the firm. By contrast, our findings diverge from Molero and Buesa (1998) concerning Spanish innovative companies, since these authors find that larger companies tend to undertake R&D with more regularity than smaller ones. This discrepancy is not strange because our methodology is more similar to that of Geroski et al. (1997), who also use patents (and innovation) data to measure persistence of innovative activities. Molero and Buesa, by contrast, measure regularity of innovative activities with data on R&D projects undertaken over the 1984–94 period. In addition it has to be borne in mind that we use a truncated sample of firms where all, even the smallest, are giant multinationals. Thus, our results on the relationship between size of the company and the period during which firms remain innovative cannot be generalized.

In what follows we test the bivariate association of a categorical variable indicating the industry in which the company markets most of its products (INDUSTRY) and the two variables denoting the length of spells (SPELLUT and SPELLDES), respectively. The H_o null hypothesis is that INDUSTRY and each of the variables indicating the length of spells (SPELLUT and

[19] We used exact tests (Monte Carlo) owing to the problem of thin cells. In all cases the confidence interval is set at 99%.

Table 6
Crosstabulation of UTILITY and SPELLUT

			Value	Asymptotic, SE[a]	Approximate T[b]	Approximate sig.	Monte Carlo sig.		
							Sig.	Confidence interval 99% Lower limit	Higher limit
A: *Directional measures*									
Ordinal by ordinal	Somer's *d*	Symmetric	0.870	0.018	49.199	0.000	0.000[c]	0.000	0.000
		UTILITY dependent	0.879	0.021	49.199	0.000	0.000[c]	0.000	0.000
		SPELLUT dependent	0.861	0.018	49.199	0.000	0.000[c]	0.000	0.000
Nominal by interval	Eta	UTILITY dependent	0.944						
		SPELLUT dependent	0.946						
B: *Symmetric measures*									
Ordinal by ordinal	Kendall's τ-b		0.870	0.018	49.199	0.000	0.000[c]	0.000	0.000
	Kendall's τ-c		0.859	0.017	49.199	0.000	0.000[c]	0.000	0.000
	Gamma		0.959	0.015	49.199	0.000	0.000[c]	0.000	0.000
	Spearman correlation		0.944	0.011	27.090	0.000	0.000[c]	0.000	0.000
N of valid cases			92						

[a] Assuming the alternative hypothesis.
[b] Using the asymptotic Stad. Error based on the null hypothesis.
[c] Based on 10,000 tables sampled with the initial seed 200,000.

Table 7
Crosstabulation of DESIGN and SPELLDES

			Value	Asymptotic, SE[a]	Approximate T[b]	Approximate sig.	Monte Carlo sig.		
							Sig.	Confidence interval 99% Lower limit	Higher limit
A: Directional measures									
Ordinal by ordinal	Somer's *d*	Symmetric	0.758	0.037	11.625	0.000	0.000[c]	0.000	0.000
		SPELLDES dependent	0.672	0.056	11.625	0.000	0.000[c]	0.000	0.000
		DESIGN dependent	0.868	0.033	11.625	0.000	0.000[c]	0.000	0.000
Nominal by interval	Eta	SPELLDES dependent	0.925						
		DESIGN dependent	0.858						
B: Symmetric measures									
Ordinal by ordinal	Kendall's τ-b		0.764	0.037	11.625	0.000	0.000[c]	0.000	0.000
	Kendall's τ-c		0.656	0.056	11.625	0.000	0.000[c]	0.000	0.000
	Gamma		0.977	0.024	11.625	0.000	0.000[c]	0.000	0.000
	Spearman correlation		0.834	0.038	14.334	0.000[d]	0.000[c]	0.000	0.000
Interval by interval	Pearson's *R*		0.851	0.031	15.343	0.000[d]	0.000[c]	0.000	0.000
N of valid cases			92						

[a] Assuming the alternative hypothesis.
[b] Using the asymptotic Std. Error based on the null hypothesis.
[c] Based on 10,000 tables sampled with the initial seed 200,000.
[d] Based on the normal approach.

SPELLDES) are not associated. We fail to reject the null hypothesis of no association between INDUSTRY and SPELLUT ($\chi^2 = 11.495$, $P = 0.487$, Monte Carlo bilateral = 0.502; Fisher's exact test = 12.812, Monte Carlo bilateral = 0.344). We also fail to reject the null hypothesis of association between INDUSTRY and SPELLDES ($\chi^2 = 11.246$, $P = 0.08$, Monte Carlo bilateral = 0.08; Fisher's exact test = 0.475, Monte Carlo bilateral = 0.118).

In this, our results also depart from Molero and Buesa's, who find differences in the regularity of R&D activities among industries. A reason for divergence could be that we analyse within-industry sub-sectors while they study firms belonging to a broad range of industries. These authors explain differences in regularity in R&D activities among firms in different sectors by differences in technological opportunities. Instead, technological opportunity is relatively similar within the multinational agri-food sector (Alfranca et al., accepted), a circumstance that could account for FBMs in different agri-food sub-sectors displaying similar innovative behaviour.

5.5. The length of technical and design innovative spells are associated

Here we test whether the length of technical and design spells (SPELLUT and SPELLDES, respectively) are associated. The rank order correlation coefficient shows moderate though statistically significant association (Spearman's $\rho = 0.51$, $P = 0.000$, Monte Carlo sig. = 0.00, $N = 92$). Kendall's τ (b and c) provides similar results (τ-b = 0.44, P = 0.000, Monte Carlo sig. = 0.000; τ-c = 0.40, $P = 0.000$, Monte Carlo sig. = 0.000). Companies that patent technical innovations continuously for many years tend also to remain constantly active in the design field for long periods of time.

6. Conclusions

In this article, we have researched the temporal pattern of innovation in the world's largest food and beverage multinationals. Our most important result is that, though most innovative spells are very short, the bulk of patents in the multinational agri-food sector were granted to companies who innovate persistently over long periods of time. In other words, a relatively small core of persistent innovators and a fringe of numerous single, and especially occasional, inventors direct technological change in the sector. The pattern is similar in the technical (utility) and designs fields.

We have also identified different types of innovators. Most FBMs remain continuously innovative only for short periods of time. Single patentors, which account for the bulk of the companies, produce technical innovations constantly for maximum periods of four years and design innovations for three; they contribute only a small share (9%) of technical patents but most (44%) of the design patents. Second, there are medium strata of sporadic innovators who amount to 15–25% of the companies and supply a moderate share of design (24%) and technical (utility) patents (10%), respectively. Finally, a small number of continuous innovators (22% of firms) patenting for periods of 18 consecutive years supply around 80% of the utility patents in the multinational agri-food sector. Persistent designers amount to only 8% of FBMs but are granted 32% of design patents. As in other studies (Cefis and Orsenigo, 2001; Geroski et al., 1997), here persistent patentors supply a disproportionately high share of the total number of patents, especially in the technical field. However, concentration of patent production is lower among the top group of FBMs analysed here than the among the national companies studied by Geroski et al. (1997).

We find a positive statistical association between the timing and the volume of patenting, in which we coincide with previous research (Geroski et al., 1997; Malerba et al., 1997; Cefis and Orsenigo, 2001). The longer the FBM remains continuously innovative, the larger its annual average production of both technical and design innovations. While timing and volume of patenting are associated, the full positive effects of persistent innovation are not immediately felt at the company level but only after a relatively long period of time devoted to constant patenting. This circumstance points to the advantages of persisting in innovative activities instead of stopping after the few first successes. Only after a minimum period do the number of patents granted to a firm finally snowball, especially in the technical field (utility). Geroski et al. (1997) also note a threshold factor in the relationship between the length of spells and the production of innovation. However, their findings suggest rather that higher levels of initial innovation trigger long innovative spells.

One of the aims of our research has been to develop a better understanding of accumulative innovation processes. We have found that the innovators who annually produce more technical and design innovations in the multinational agri-food sector generate steady flows of inventions over the years, not short bursts of patents followed by long interruptions. Most of the patents granted to this multinational industry follow this model. Thus, the pattern of production of innovation in this sector characterized by the control of very large companies over technology is different from that described by Clark (1985) in new industries, where a great number of new entrants are still searching for engineering designs adapted to consumer needs. In such new and still undefined industries authors do not observe regular flows of innovations, as we do here, but rather short bursts of inventions, and then periods with no innovations followed by others of effervescent patenting activity. Our findings concerning steady flows of innovation among the heavy patentors in the multinational agri-food sector are new elements that confirm Galizzi and Venturini's (1996) views and our own previous work (Christensen et al., 1996; Alfranca et al., 2002) about technological change in food and drinks being incremental and cumulative. The production of incremental innovation proceeds by within-company long-lasting flows. Given that many firms follow this scheme simultaneously over a long period of time, technological competition in the multinational agri-food sector is likely to be, in Niosi's words (Niosi, 2000), synchronous rather than sequential. Here dominant firms are not systematically dislodged, as in some high-tech industries.

Yet, in many cases innovation in the multinational agri-food sector is an occasional issue. As mentioned above, a myriad of short-run projects coexist with long-run R&D. Innovative spells lasting fewer than four years are 84% of the total number of spells over the period. The proliferation of short-term projects has also been noted by Geroski et al. (1997) in British industry.

In the debate about what determines patterns of innovation, specifically whether they are characteristics intrinsic to sectors or to the managers (Miller and Blais, 1992), our study seems to support the former position. Most of the innovations produced by the very large companies which influence the food and drink industry worldwide are generated following a typical model of steady, lengthy flows of innovative activity. However, one observes substantial within-sector differences among the companies. It is surprising that, even in the top group, some FBMs innovate only occasionally. In other cases, persistent innovators do not seem to obtain all the fruits from their constant effort, at least in terms of the number of patents. Such differences in a homogeneous industry like that analysed here suggest that strategies and managers' decisions (and luck) also play their part in determining patterns of innovation and temporal dynamics.

Why do some FBMs have the ability to keep innovating and others not? With the available information it is difficult to answer this question. First, persistent innovators are not especially large companies. In this, we coincide with Geroski et al. (1997) and depart, by contrast, from Molero and Buesa (1998) as well as Cefis and Orsenigo (2001), who find that persistence in innovation is positively associated with size of the company. However, while our results seem to transmit the optimistic view that a food company does not need to be very big to benefit from constant innovation, further investigation of the question is needed since, in our sample, even smaller FBMs are very large. Second, persistent FBMs do not tend to belong to a specific branch of the agri-food industry, probably because technological opportunity is quite similar within this multinational sector. The salient traits of persistent innovators in this industry are, rather, an integrated view of the innovative process and a substantial creativity evidenced in a wealth of patents. They are probably also able to accumulate managerial expertise in the R&D field, and tacit knowledge.

In this respect, we have also noted that firms remaining innovative for long periods of time in the technical area tend also to remaining innovative in the design field. This result corroborates previous findings in that technical and design innovations are complementary rather than alternative strategies (Alfranca et al., accepted). However, FBMs' spells in innovative design tend to be shorter than spells in technical innovation.

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