ELSEVIER

Research Policy 25 (1996) 451–478

research policy

Schumpeterian patterns of innovation are technology-specific

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Received in final form May 1995

Abstract

This paper examines the patterns of innovative activities at the technological and country levels, using patent data for 49 technological classes in six countries (USA, Japan, Germany, France, United Kingdom and Italy).

It is shown that the patterns of innovative activities differ systematically across technological classes, but are remarkably similar across countries for each technological class. In particular, two groups of technological classes are identified: '*Schumpeter Mark I*' and '*Schumpeter Mark II*'. In these two groups innovative activities are structured and organized in different ways. The first represents a *widening* pattern: concentration of innovative activities is low, innovators are of small economic size, stability in the ranking of innovators is low and entry of new innovators is high. The second represents a *deepening* pattern: concentration of innovative activities is higher than in the first group, innovators are of larger economic size, stability in the ranking of innovators is greater, and entry is lower. The former group comprises mechanical technologies and traditional sectors, while the latter includes chemicals and electronics.

This result suggests that technology-related factors (such as *technological regimes*, defined in terms of conditions of opportunity, appropriability, cumulativeness and properties of the knowledge base) play a major role in determining the specific pattern of innovative activities of a technological class across countries. Within these constraints, country-specific factors introduce differences across countries in the pattern of innovative activities for a specific technological class.

Finally, the relationships between the specific features of the patterns of innovative activities and international technological specialization are examined. Technological advantages appear in general to be linked to higher degrees of asymmetries among innovators, higher stability of the ranking of innovators, smaller economic size of the innovating firms and lower entry rates of new innovators. These relationships, however, are different in the two groups of technological classes. In Schumpeter Mark I (widening) technological classes, international technological specialization is associated with relatively higher degrees of asymmetries among innovators and entry of new innovators (as well as smaller firm size) while in Schumpeter II (deepening) technological classes, international technological specialization is linked to the existence of a stable but competitive core of persistent innovators.

1. Introduction

The ways innovative activities take place in industries and technologies may be quite different. One may find that in certain technologies innovative activities are concentrated among few major innovators while in others innovative activities are distributed among several firms. In certain technologies large firms do the bulk of innovative activities while in others small firms are quite active. Finally, in some technologies new innovators continuously appear while in others only established firms innovate; and so on.

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0048-7333/96/$15.00
SSDI 0048-7333(95)00840-3

This difference in the structure of innovative activities may be related to a fundamental distinction between *Schumpeter Mark I* and *Schumpeter Mark II* technologies. Schumpeter identified two major patterns of innovative activities. The first one, labelled by Nelson and Winter (1982) and Kamien and Schwartz (1982) Schumpeter Mark I, was proposed in *The theory of economic development* (Schumpeter, 1934). This pattern of innovative activity is characterized by 'creative destruction' with technological ease of entry and a major role played by entrepreneurs and new firms in innovative activities. The second one, labelled Schumpeter Mark II, was proposed in *Capitalism, socialism and democracy* (Schumpeter, 1942). In this work Schumpeter discussed the relevance of the industrial R & D laboratory for technological innovation and the key role of large firms. This pattern of innovative activity is characterized by 'creative accumulation' with the prevalence of large established firms and the presence of relevant barriers to entry for new innovators. The Schumpeterian Mark I and Mark II patterns of innovation could be labelled also *widening* and *deepening*. A widening pattern of innovative activities is related to an innovative base, which is continuously enlarging through the entry of new innovators, and to the erosion of the competitive and technological advantages of the established firms. A deepening pattern of innovation, on the contrary, is related to the dominance of a few firms which are continuously innovative through the accumulation over time of technological and innovative capabilities (Malerba and Orsenigo, 1995b). [1]

However, very little is known about the empirical relevance of these two characterizations of technological change. The questions at stake here concern: first, is it possible to observe in the data patterns of innovation that more closely resemble the Schumpeter Mark I or the Schumpeter Mark II model? Second, what are the determinants of the different observed patterns of innovative activities? Third, are the observed patterns related to technological performance in any meaningful way? For instance, is the technological specialization of countries associated with creative destruction or creative accumulation?

Answers to these questions would have important implications for our understanding of the determinants of the patterns of technological change and thereby for the theory of industrial dynamics, growth and trade. Furthermore, the quality of the debate about alternative policy prescriptions largely depends on this issue.

In this paper, we provide some empirical evidence about these questions. First, we ask which (if any) of the models hypothesized by Schumpeter is observed in the data. Second, we discuss whether the observed patterns of innovative activities are technology-specific, country-specific or both.

In this respect, it is important to realize that these hypotheses are linked to Schumpeter. A first interpretation of the Schumpeterian patterns relates to time. In the early stages of capitalism or in the early stages of the evolution of an industry, innovative activities are more similar to the Schumpeter I (widening) model. Later on, in the development of capitalism (or in the evolution of a technology), the patterns of innovative activities become more alike the Schumpeter II (deepening) model.

The other hypothesis refers instead to the working of technology-specific and country-specific factors. One could argue in fact that the *technology-specific* (and industry-specific) hypothesis may be related to the distinction between the traditional sectors which characterized the pages of *The theory of economic*

[1] During the last forty years this characterization of innovative activities by Schumpeter has encouraged different scholarly traditions aiming at the empirical verification of the two patterns. The first, and older, tradition was mainly centered on the firm. It attempted to assess the role of firm size and of monopoly power in innovation (Kamien and Schwartz, 1982). The inconclusive results obtained in these empirical analyses are due to the neglected role of opportunity and appropriability conditions in the various industries (Levin et al., 1985) and of the endogenous relationship between firm size, concentration and technological change (Nelson and Winter, 1982). A second, and more recent, tradition has considered Schumpeter Mark I and II models according to the specific stage of an industry life cycle. According to the industry life cycle view, early in the history of an industry, when technology is changing very rapidly, uncertainty is very high and barriers to entry very low, new firms are the major innovators and are the key elements in industrial dynamics. On the contrary, when the industry develops and eventually matures and technological change follows well-defined trajectories, economies of scale, learning curves, barriers to entry and financial resources become important in the competitive process. Thus, large firms with monopolistic power come to the forefront of the innovation process (Utterback and Abernathy, 1975; Gort and Klepper, 1982; Klepper, 1992.)

development and the chemical and electrical sectors which characterized the pages of *Capitalism, socialism and democracy*. On the contrary, one could argue that the *country-specific* argument may be related to the distinction between the fragmented and entrepreneurial Austrian industrial structure of *The theory of economic development* and the concentrated oligopolistic American industrial structure of *Capitalism, socialism and democracy*.

More generally, it is possible to claim that the first hypothesis (*patterns are technology-specific*) is related to the existence of technological imperatives which are rather invariant across countries. These imperatives may be related to the specific features of a technology and in particular to the properties of the relevant *technological regime*. Inspired by Nelson and Winter (1982), Winter (1984), Dosi (1988) and Cohen and Levin (1989), we defined technological regimes as combinations of opportunity and appropriability conditions and degrees of cumulativeness of technological advances (Malerba and Orsenigo, 1990, 1993). These papers examined the link between technological regimes and the patterns of innovative activities both at the conceptual and the empirical level. [2]

According to this interpretation, the widening and deepening Schumpeterian patterns of innovation may be seen as the results of specific technological regimes. Widening patterns are determined by high opportunity and low appropriability conditions, which favor the continuous entry of new innovators in the industry, and by low cumulativeness conditions, which do not allow the persistence over time of innovative success at the firm level. Deepening patterns are determined by high opportunity, appropriability and cumulativeness conditions, which allow innovators to continuously accumulate technological knowledge and capabilities and to build up innovative advantages over non-innovators and potential entrants (Malerba and Orsenigo, 1993).

These patterns of innovations ought to be rather invariant across countries, as long as opportunity, appropriability and cumulativeness conditions – i.e. the dimensions of technological regimes that affect the widening and deepening patterns of innovation – are similar across countries. There is indeed some evidence that appropriability and cumulativeness conditions are rather similar across advanced industrialized countries (see Malerba and Orsenigo, 1990; Heimler et al., 1993, for an analysis of the Italian and American cases) across a wide range of technologies. The ability to generate and exploit opportunity conditions is however less similar among advanced countries, because this ability is related to the level and range of university research, the presence and effectiveness of science–industry bridging mechanisms, vertical and horizontal links among local firms, user–producer interaction and the types and level of firms' innovative efforts (Nelson, 1993).

On the other hand, the second hypothesis (*patterns of innovation are country-specific*) may be related to the existence of major differences among countries in their historical industrial development, in the competence and organization of their firms and in the architecture and policies of their specific national systems of innovations. The contributions of Freeman (1982), Lundvall (1993) and Nelson (1993) have shown that major differences exist across countries in their institutional architectures, public policies and competences and that these factors have major effects on international technological performance.

In addition to the discussion of these issues, in the final part of the paper we provide some preliminary evidence about the relationships between the patterns of innovation and countries' technological specialization.

We examine the patterns of innovative activities for six large industrialized countries (Germany, France, the United Kingdom, Italy, the United States and Japan) and for 49 technological classes. We greatly expand the analysis done in a previous paper. In Malerba and Orsenigo (1995b), we used a smaller set of countries (Germany, France, the United Kingdom, and Italy), technological classes (33 classes) and firms (only those firms for which we found

[2] Opportunity conditions refer to the ease of innovation by would-be innovators, and are related to the potential for innovation of each technology. Appropriability conditions refer to the ability of innovators to protect their innovations from imitation, and therefore to reap profits from their innovations. Cumulativeness conditions refer to the degree to which new technology builds on existing technology. At the firm level, cumulativeness may imply that today's innovators have a higher probability of continuing to innovate in the future than today's non-innovators (Nelson and Winter, 1982).

economic data) and a different database (OTAF-SPRU database on American patents granted in the period 1968–1986). We found that technologies differ quite drastically in the way innovative activities are structured and organized at the firm level according to the Schumpeter Mark I and Schumpeter Mark II models. We found also that remarkable similarities exist in the patterns of innovative activities in most technological classes across the four large European countries considered in that paper. Chemicals and electronics have the characteristics of the Schumpeter Mark II model, whilst the mechanical classes show a Schumpeter Mark I model. This led us to propose that the specific features of technologies and the relevant technological regimes may act as imperatives in shaping the structure of innovative activities rather similarly across countries.

The paper is organized in the following way. Section 2 presents the data, while Section 3 introduces the indicators which are used to identify the two Schumpeterian patterns of innovative activities. Section 4 and Section 5 discuss the hypotheses regarding respectively the technological-specificity and the country-specificity of the Schumpeterian patterns of innovation. In Section 6 some relationships between the variables which define the Schumpeterian patterns of innovation and countries' technological specialization are examined. Section 7 gives conclusions.

2. Data

Our analysis is based on patent data. Criticisms of the use of patent data are well known. Not all innovations are patented by firms. Patents cannot be distinguished in terms of relevance unless specific analyses on patent renewals or citations are done. Finally, different technologies are differently patentable and different types of firms may have different propensities to patent. However, patents represent a very homogeneous measure of technological novelty across countries and are available for long times series. They also provide very detailed data at the firm and the technological class levels. As a consequence, they are an invaluable and unique source of data on innovative activity.

This paper has used European Patent Office (EPO) data for the period 1978–1991. The data refer to patent applications to EPO by firms and institutions (universities, public research laboratories, etc.) of various countries, with the exclusion of individual inventors. [3]

The EPO database has been elaborated at the level of individual firms and institutions [4] (excluding individual inventors) for six countries: the United States, Japan, Germany (Federal Republic), France, the United Kingdom, Italy.

As far as the United States is concerned, 133,475 patents and 11,476 firms have been considered; for Germany, 108,118 patents and 8,495 firms; for France, 43,986 patents and 5,671 firms; for the United Kingdom, 35,175 patents and 6,055 firms; for Italy, 15,175 patents and 3,803 firms, and for Japan 81,217 and 3,990 firms. The small number of Japanese firms may imply that the data concerning this country have to be considered with great care. In addition, for the four European countries data on the size of the innovators have been gathered: 56% of the German firms, 49% of the French firms, 34% of the British firms and 51% of the Italian firms have been covered. Economic data on firms applying for patents concern size in terms of employees in 1991. Therefore a bias may be present in the analysis in favor of firms active during the early 1990s. Firms that are part of business groups have been treated in the present analysis as individual companies. Since EPO is located in Germany, German firms are over-represented in the sample. However because we aim to discuss not absolute technological performance,

[3] Although some of these individual inventors work for a firm (or institution), the majority of individual inventors includes individuals who do not work in firms or other institutions and owners of small firms who record the patent in their name. Thus, the exclusion of individual inventors leads to the underestimation of the innovative activities of smaller companies. The share of the patents held by private individuals is however usually larger in technological classes and countries where the role of small firms is greater. The share of patents held by private individuals calculated over the total number of patents held by the institutions considered in our database is 2.5% in Germany, 2.52% in France, 2.10% in the UK, 2.88% in Italy, 1.09% in the USA and 1.49% in Japan. Notice also that patents that are applied for by more than one institution (co-patents) have been attributed to each one of the co-patentees (and therefore have been counted as many times as the number of co-patentees).

[4] Hereafter, for sake of brevity, we shall use the term 'firm' instead of 'firms and institutions'.

but the structure of innovative activity at the industry level, we think that this does not create too serious a distortion in our results.

In the analysis, 49 technological classes are considered (see appendix, Table A.1). These classes have been created starting from the various subclasses (four digits) of the International Patent Classification (IPC) and grouping them according to specific applications. [5] Because the analysis has been carried out for the period 1978–1991, it is possible that over the period a technological class may have moved from a Schumpeter Mark I to a Schumpeter Mark II group. We have attributed, however, a technological class to either the Schumpeter Mark I or to the Schumpeter Mark II group on the basis of the data for the whole period.

3. Patterns of innovative activities: measures and classification

3.1. Indicators of the patterns of innovative activities

Patterns of innovative activities have been analyzed on the basis of a set of indicators which attempt to capture some of the essential features of the two Schumpeterian 'models'. Specifically, we have developed measures of the following characteristics of innovative activities:

(i) Concentration and asymmetries of innovative activities among firms;
(ii) Size of the innovating firms;
(iii) Change over time in the hierarchy of innovators;
(iv) Relevance of new innovators as compared to established ones.

The first two sets of indicators (concentration and firm size) have been conventionally used in the traditional discussions of the Schumpeterian hypotheses. Clearly, they are meant to measure the extent to which innovative activities tend to be concentrated in few firms or are evenly distributed across a large number of firms, and whether large firms or small firms are the main source of innovation in any particular technological class. The other two sets of measures are newer in this kind of analysis: they aim to shed light on the degree of 'stability' and 'creative accumulation' or 'dynamism' and 'creative destruction' in the organization of innovative activity. In particular, these indicators try to identify dimensions related to the following questions:

– Is the list of yesterday's main innovators the same as today's list or have other firms become more innovative?
– How relevant are new innovators as compared to old ones?

Thus, for each of the 49 technological classes the following indicators have been constructed using patent data:

Concentration of innovative activities. Concentration is measured by the concentration ratio of the top four innovators (*C4*). *C4* is quite high in sectors such as organic chemicals, macromolecular compounds, agricultural chemicals, aircraft, computers, telecommunications and nuclear technology. It is low in clothing, furniture, agriculture, mining, chemical apparatus, industrial automation, industrial machinery and equipment, civil engineering, mechanical engineering and measuring equipment (see Table A.2). Moreover, we calculated the Herfindahl index (*HERF*) to measure how symmetric or asymmetric is the distribution of innovative activities among firms. *HERF* is high for organic chemicals and macromolecular compounds, miscellaneous chemical compounds, electronic components and telecommunications, while it is low for clothing, furniture, agriculture, mining, metallurgy, industrial automation, industrial machinery, material handling apparatus, civil engineering, mechanical engineering, mechanical and electric technologies and sports (see Table A.3).

Size of the innovating firms. This is calculated simply as the share of total patent applications applied for by firms with more than 500 employees (*SIZE*). *SIZE* is high in inorganic chemicals, organic chemicals, macromolecular compounds, adhesives, agricultural chemicals, computers and other office

[5] Details on the procedures of construction of the classification are available on request.

equipment, while it is low in clothing, furniture, agriculture and sports (see Table A.4).

Stability in the hierarchy of innovators. Stability is measured by the Spearman rank correlation coefficient between firms innovating in 1978–1985 and firms innovating in 1986–1991 (*SPEATOT*). *SPEATOT* is low for clothing, furniture, agriculture, chemical processes, machine tools, industrial automation, civil engineering and sports, while it is

Table 1
Correlation between the indicators of the patterns of innovative activities in each country

	C4	*HERF*	*SIZE*	*SPEATOT*	*SPEACORE*	*ENTRY*
Germany						
C4	1	0.89818	0.33844	0.36844	0.57346	−0.57813
HERF		1	0.09239	0.28063	0.48148	−0.46861
SIZE			1	0.36835	0.22132	−0.37634
SPEATOT				1	0.30587	−0.84354
SPEACORE					1	−0.53782
ENTRY						1
France						
C4	1	0.92008	0.47724	0.49505	0.12514	−0.42053
HERF		1	0.33259	0.51173	0.12194	−0.35631
SIZE			1	0.32049	−0.01212	−0.35009
SPEATOT				1	0.36538	−0.83329
SPEACORE					1	−0.33577
ENTRY						1
United Kingdom						
C4	1	0.83724	0.78668	0.6277	0.38625	−0.70286
HERF		1	0.6824	0.48092	0.3251	−0.52961
SIZE			1	0.78237	0.53917	−0.86022
SPEATOT				1	0.44551	−0.84832
SPEACORE					1	−0.47762
ENTRY						1
Italy						
C4	1	0.88115	0.64289	0.57945	0.37243	−0.35003
HERF		1	0.53631	0.52956	0.37258	−0.40617
SIZE			1	0.59229	0.19664	−0.37144
SPEATOT				1	0.46768	−0.65505
SPEACORE					1	−0.53974
ENTRY						1
Japan						
C4	1	0.84348		−0.09938	0.26162	−0.26614
HERF		1		−0.23929	0.20355	−0.16748
SPEATOT				1	0.27068	−0.80604
SPEACORE					1	−0.29935
ENTRY						1
United States						
C4	1	0.90887		0.03358	0.39853	−0.4868
HERF		1		−0.06819	0.34564	−0.37406
SPEATOT				1	0.53147	−0.76739
SPEACORE					1	−0.69282
ENTRY						1

Source: EPO - Center for Research on Internationalization (CESPRI) (Bocconi University) database.

Table 2
Principal components analysis: eigenvectors

PRIN1		Germany	France	United Kingdom	Italy	Japan	United States
C4		0.527	0.516	0.526	0.530	0.666	0.576
HERF		0.490	0.508	0.469	0.530	0.638	0.535
SPEATOT		0.450	0.509	0.491	0.506	0.090	0.301
ENTRY		−0.529	−0.464	−0.512	−0.427	−0.377	−0.540
Eigenvalue	PRIN	2.729	2.772	3.019	2.715	1.946	2.318
	PRIN	1.049	0.992	0.699	0.855	1.799	1.484
	PRIN	0.135	0.173	0.163	0.324	0.156	0.118
	PRIN	0.087	0.063	0.120	0.106	0.100	0.080

Source: EPO-CESPRI database.

high for gas and oil, organic chemicals, macromolecular compounds, new materials, adhesives, drugs, aircraft, electronic components and telecommunications (see Table A.5). We computed also a measure of the stability of the hierarchy of only those firms which innovate continuously over time (Spearman rank correlation coefficient between the hierarchies of firms innovating in 1978–1985 and 1986–1991, (*SPEACORE*). The difference between *SPEATOT* and *SPEACORE* is that the first indicator considers also firms entering and exiting from the population of innovators. Thus, when turbulence is generated by new entrants and exiters but incumbent firms mantain over time a stable ranking, one might observe technological classes characterized by high values of *SPEACORE* but low values of *SPEATOT*. *SPEACORE* has a low positive value or a negative value in furniture, agriculture, mining, agricultural chemicals, chemical processes and machine tools, while it has a high positive value in organic chemicals, macromolecular compounds, computers and office equipment (see Table A.6).

Entry of new innovators. The relevance of new innovators is measured by the share of patent applications by firms applying for the first time in a given technological class in the period 1986–1991 over the total number of patents in the same period (*ENTRY*). It must be noted that this indicator measures innovative entry and not entrepreneurial birth: a new innovator may in fact have been around for quite a long time. Notice also that *ENTRY* refers to gross entry (mortality has been calculated but not used in this analysis) and to entry in a specific sector. [6] *ENTRY* is low for organic chemicals, macromolecular compounds, electronic components, consumer electronics and telecommunications, while it is high for clothing, furniture, agriculture, mining, chemical processes, machine tools, civil engineering, lighting systems and sports (see Table A.7).

3.2. Schumpeterian patterns of innovations

Schumpeterian patterns of innovation may be identified by the existence of specific and systematic relationships between these measures. In particular, the Schumpeter Mark I (widening) model should be characterized by low concentration and asymmetries in innovative activities, low stability in the ranking of innovators and high entry of new innovators and small size of innovators. Conversely, the Schumpeter Mark II (deepening) model should be characterized by high concentration and asymmetries in innovative

[6] In a recent paper (Malerba and Orsenigo, 1995a), we have examined the patterns of innovative entry and exit in more detail, distinguishing between net entry and lateral entry. The first refers to firms that innovate for the first time; the second to entrants in a technological class, that have innovated in other technological classes. The sectoral patterns of innovative entry and exit are remarkably similar across countries. Around one third (Italy) and one half (Japan) of the entrants are lateral entrants. Lateral entry is generated to a considerable extent by lateral technological diversification of large firms that enter into new technologies. Net entrants are conversely small firms with few patents. Moreover, a large fraction of net entrants is composed of occasional innovators, i.e. they do not innovate any longer after the initial patents.

Table 3
Principal components analysis: values of the first component, observation PRIN 1

Technological classses	Germany	France	United Kingdom	Italy	Japan	United States
1	−0.570	−1.031	1.904	0.092	−0.530	0.250
2	−1.219	0.463	−1.658	1.109	–	−0.728
3	−1.461	−1.629	−1.575	−1.040	−1.244	−1.751
4	−1.905	−1.788	−1.108	−1.355	−1.429	−1.657
5	−1.112	0.814	−0.651	−0.393	−0.441	0.355
6	0.296	0.997	0.917	0.321	−0.423	0.998
7	0.001	0.418	0.402	−0.428	−1.149	−0.222
8	2.126	0.852	1.581	0.633	−0.252	0.518
9	1.772	0.902	1.147	1.054	−0.280	0.830
10	−0.120	0.133	0.103	−0.373	−0.614	0.002
11	1.213	−0.193	0.524	−0.340	−0.450	0.204
12	0.576	0.255	0.169	0.123	−0.521	−0.061
13	–	−0.150	–	1.612	0.991	1.685
14	−0.604	−0.269	−0.141	−0.984	−1.007	−0.357
15	0.392	0.236	1.142	−0.098	−0.508	−0.054
16	−0.284	−0.816	−0.447	−0.960	−0.181	−0.582
17	−0.810	−0.570	−0.690	0.525	−0.185	0.202
18	0.452	−0.743	0.429	−1.136	−0.428	0.241
19	1.035	0.156	0.636	−0.355	−0.442	−0.459
20	−0.915	−1.650	0.088	−0.970	−1.062	−0.175
21	−0.219	0.256	0.171	−0.585	−0.233	−0.125
22	−0.742	−0.246	−0.696	−0.237	−0.740	−0.318
23	−0.610	−0.869	−0.597	−0.688	1.884	−0.673
24	−0.651	−0.937	−0.541	−0.730	−0.974	−0.559
25	0.867	0.895	−0.420	−0.410	−0.851	–
26	0.006	0.500	0.246	0.237	0.399	−0.175
27	0.476	–	0.859	−0.105	0.125	1.104
28	−0.896	−0.645	−1.190	−0.173	0.269	−1.795
29	−0.996	−1.339	−0.932	−0.707	−1.099	−0.650
30	−1.076	−1.204	−1.261	−0.996	−1.065	−1.388
31	0.348	0.665	0.344	0.063	0.214	−0.085
32	−0.680	−0.003	−0.055	−0.759	−0.292	−0.411
33	−0.933	−0.193	−1.004	−0.840	−0.720	−0.678
34	−0.531	−0.104	−1.063	−0.496	0.271	−1.277
35	−0.348	−0.846	−1.043	−0.617	0.764	−0.684
36	−0.060	−0.268	−0.551	−0.536	−0.446	−0.418
37	0.399	0.801	0.489	1.196	0.552	0.319
38	0.694	0.633	0.331	0.093	0.725	−0.843
39	0.716	0.323	−0.384	0.911	0.572	1.009
40	0.498	−0.024	0.054	–	0.650	1.579
41	0.473	−0.141	−0.348	−0.397	0.020	0.006
42	1.445	0.767	0.258	1.030	1.006	0.659
43	0.664	0.444	−0.024	0.367	0.887	−0.001
44	1.734	0.509	0.457	1.330	1.312	1.469
45	–	1.043	1.918	–	1.441	1.117
46	−1.758	−1.061	−1.628	−0.979	−1.750	−1.367
47	1.090	0.724	0.124	0.021	1.500	−0.140
48	0.685	–	0.950	1.280	–	–
49	−1.460	−1.254	−0.636	−0.730	−0.269	−1.188

Source: EPO-CESPRI database.

activities, high stability of the hierarchy of innovators, low entry of new innovators and large size of innovators.

Indeed, coherent relationships exist between these indicators.

First, correlation analysis for the 49 technological

Table 4
Correlation across countries between the indicators of the patterns of innovative activities

	Germany	France	United Kingdom	Italy	Japan	United States
C4						
Germany	1	0.59921	0.74365	0.60978	0.36826	0.57418
France		1	0.60772	0.78217	0.5296	0.7151
United Kingdom			1	0.61915	0.27081	0.63422
Italy				1	0.59192	0.78836
Japan					1	0.50984
United States						1
HERF						
Germany	1	0.44009	0.67374	0.41373	0.22714	0.46986
France		1	0.31332	0.48204	0.27073	0.64021
United Kingdom			1	0.30577	0.14915	0.46103
Italy				1	0.43517	0.41602
Japan					1	0.22912
United States						1
SIZE						
Germany	1	0.27832	0.42348	0.41249		
France		1	0.3893	0.60132		
United Kingdom			1	0.55402		
Italy				1		
SPEATOT						
Germany	1	0.62841	0.54756	0.18609	0.52296	0.71902
France		1	0.60859	0.31387	0.54518	0.62229
United Kingdom			1	0.56203	0.5753	0.71399
Italy				1	0.45464	0.33727
Japan					1	0.74669
United States						1
SPEACORE						
Germany	1	0.23889	0.21171	−0.06695	0.01629	0.47293
France		1	0.09417	0.26402	0.04789	−0.00052
United Kingdom			1	0.04585	0.20755	0.41636
Italy				1	0.33314	0.28343
Japan					1	0.04532
United States	1					
ENTRY						
Germany	1	0.68724	0.70058	0.47353	0.52263	0.65348
France		1	0.5143	0.40817	0.46644	0.68772
United Kingdom			1	0.42547	0.47762	0.71692
Italy				1	0.68416	0.4802
Japan					1	0.51199
United States						1

Source: EPO-CESPRI database.

Table 5
Patterns of innovative activities across countries (average over 49 technological classes)

		Germany	France	United Kingdom	Italy	Japan	United States
C4	Av	36.70	32.90	34.00	37.60	34.90	29.50
	Std	19.70	15.20	18.60	20.10	16.50	17.70
HERF	Av	0.07	0.05	0.07	0.08	0.07	0.06
	Std	0.08	0.05	0.10	0.09	0.08	0.09
SIZE	Av	52.30	43.90	45.90	33.60	–	–
	Std	15.80	14.90	18.20	19.60	–	–
SPEATOT	Av	−0.13	−0.29	−0.36	−0.35	−0.06	−0.23
	Std	0.17	0.20	0.19	0.33	0.26	0.19
SPEACORE	Av	0.55	0.46	0.47	0.37	0.56	0.52
	Std	0.20	0.21	0.20	0.50	0.26	0.18
ENTRY	Av	0.33	0.45	0.46	0.65	0.41	0.34
	Std	0.18	0.19	0.20	0.20	0.22	0.18

Source: EPO-CESPRI database.

classes shows in the European countries a positive correlation between concentration (*C4*) and asymmetries (*HERF*), stability of innovators' hierarchy (*SPEATOT* and *SPEACORE*) and (although to a lesser extent) the size of innovating firms (*SIZE*), and a negative correlation between these measures and entry of new innovators (*ENTRY*). Similar results hold for the USA and Japan. In these countries, however, there is no correlation (or a negative one) between the variable *SPEATOT* and the measures of concentration (*C4* and *HERF*) [7] (Table 1). In the case of Japan, other differences emerge which will be discussed in Section 5.3.

Second, principal components analysis (Tables 2 and 3) performed for all the technological classes identifies in all countries one dominant factor. This factor captures at least half of the variance (49% for Japan, 58% for the United States, 68% for Germany, 69% for France, 75% for the United Kingdom, 68% for Italy and 72% for the four European countries considered together). This factor discriminates in all countries between measures of concentration and asymmetries (*C4* and *HERF*) and stability of the hierarchy of innovators (*SPEATOT*) on the one hand, and the variable *ENTRY* on the other. In other words, this component captures quite neatly the distinction between Schumpeter Mark I and Schumpeter Mark II technological classes.

[7] We have no data for the size of innovating firms for the USA and Japan.

Thus, one can conclude that the relationships between the various indicators of the patterns of innovation are actually related to the two Schumpeterian models and that the two alternative models discriminate significantly between technological classes.

4. Technological imperatives and the technological specificity of Schumpeterian patterns of innovation

We examine now whether the patterns of innovative activities are technology-specific. This would be the case if similarities were observed in the pattern of innovative activities in the same technological class across countries.

Our analysis clearly suggests that technological imperatives and some basic conditions of technological regimes structure the patterns of innovative activities in each technological class across countries in a very similar way. This can be seen in different ways.

(a) The correlation coefficients for each indicator in the 49 technological classes across countries indicate that major similarities exist among countries in the sectoral patterns of innovative activities (Table 4). That is to say, in the same technological class, concentration, asymmetries, stability of the hierarchy of innovators and the role of new innovators tend to have the same values across countries. Exceptions

Table 6
Patterns of innovative activities and technological specialization: factors affecting revealed technological advantages (*RTAW*) of six countries [a]

Regression 1		Regression 2		Regression 3	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
Intercept	1.219 *	*Intercept*	0.977	*Intercept*	1.250
	[0.325]		[0.051]		[0.242]
ENTRYFIRM	−0.362	*HERF*	1.008 *	*HERF*	1.060 *
	[0.480]		[0.369]		[0.361]
HERF	1.047 *	*SPEATOT*	0.127	*ENTRYFIRM*	−0.413 *
	[0.373]		[0.120]		[0.320]
SPEATOT	0.026				
	[0.180]				
R squared	0.036	*R* squared	0.051	*R* squared	0.051
Adj. *R* squared	0.026	Adj. *R* squared	0.034	Adj. *R* squared	0.036
F value	3.619	*F* value	5.150	*F* value	5.437

Independent variables	Regression 4	Regression 5	Regression 6
	Dependent variable RTAW	Dependent variable RTAW	Dependent variable RTAW
Intercept	1.267 * * *	1.010	1.774
	[0.401]	[0.091]	[0.294]
HERF	1.287 * * *	1.241	1.430
	[0.384]	[0.378]	[0.378]
SPEATOT	−0.420 * * *	0.536 * * *	–
	[0.229]	[0.147]	–
ENTRYFIRM	0.398	–	−1.253 * * *
	[0.606]	–	[0.391]
DSchump1 [b]	−0.166	−0.163	−0.146
	[0.076]	[0.076]	[0.076]
DSchump2 [c]	0.151	0.150	0.135
	[0.072]	[0.072]	[0.072]
DumDe [d]	−0.065	−0.061	−0.038
	[0.102]	[0.102]	[0.103]
DumFr [d]	0.161	0.163	0.145
	[0.100]	[0.101]	[0.101]
DumUK [d]	0.173	0.177	0.141
	[0.103]	[0.102]	[0.102]
Dum / t [d]	0.196	0.167	0.238
	[0.112]	[0.102]	[0.110]
DumUS [d]	0.111	−0.143	−0.015
	[0.114]	[0.103]	[0.102]
R squared	0.499	0.513	0.502
Adj. *R* squared	0.108	0.034	0.096
F value	3.397	3.733	3.368

Number of observations $n = 293$.
[a] Numbers between square brackets indicate standard errors (*) significant at 99% (* *) significant at 95% (* * *) significant at 90%
[b] Dummy for Schumpeter Mark I pattern.
[c] Dummy for Schumpeter Mark II pattern.
[d] Country dummy.
Source: EPO-CESPRI database.

Table 7
Patterns of innovative activities and technological specialization (spline function): factors affecting revealed technological advantages (RTAW) of six countries [a]

Regression 1		Regression 2		Regression 3	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
Intercept	1.303 **	*Intercept*	0.953 *	*Intercept*	1.730 *
	[0.609]		[0.078]		[0.501]
HERF	2.034 *	*HERF*	2.027 *	*HERF*	2.032 **
	[0.550]		[0.547]		[0.555]
SPEATOT	0.379	*SPEATOT*	0.495 **	*ENTRYFIRM*	−1.204 ***
	[0.314]		[0.240]		[0.690]
ENTRYFIRM	−0.515	*DSchump1* [b]	−0.145	*DSchump1* [b]	−1.326 ***
	[0.890]		[0.131]		[0.693]
DSchump1 [b]	−0.397	*DHerf1* [b]	0.861	*DHerf1* [b]	0.700
	[0.865]		[0.990]		[1.012]
DHerf1 [b]	0.885	*DSpeat1* [b]	−0.912 *	*DEntry1* [b]	1.927 **
	[1.012]		[0.337]		[0.921]
DSpeat1 [b]	−0.839 ***	*DSchump2* [c]	0.123	*DSchump2* [c]	0.225
	[0.475]		[0.119]		[0.658]
DEntry1 [b]	0.368	*DHerf2* [c]	−2.048 **	*DHerf2* [c]	−1.553 ***
	[1.270]		[0.860]		[0.865]
DSchump2 [c]	0.003	*DSpeat2* [c]	0.284	*DEntry2* [c]	−0.237
	[0.790]		[0.334]		[0.922]
DHerf2 [c]	−1.989 **				
	[0.875]				
DSpeat2 [c]	0.318				
	[0.430]				
DEntry2 [c]	0.162				
	[1.170]				
R squared	0.143	*R* squared	0.141	*R* squared	0.115
Adj. *R* squared	0.108	Adj. *R* squared	0.116	Adj. *R* squared	0.090
F value	4.129	*F* value	5.655	*F* value	4.491

Regression 4		Regression 5		Regression 6	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
Intercept	2.151 *	*Intercept*	0.749 *	*Intercept*	0.910
	[0.542]		[0.096]		[0.697]
HERF	2.047 *	*HERF*	1.923 *	*HERF*	1.917 *
	[0.553]		[0.537]		[0.542]
ENTRYFIRM	1.976 *	*SPEATOT*	0.873 *	*SPEATOT*	0.822 **
	[0.743]		[0.247]		[0.337]
DSchump1 [b]	1.259 ***	*DSchump1* [b]	−0.053	*ENTRYFIRM*	−0.246
	[0.684]		[0.129]		[0.984]
DHerf1 [b]	0.998	*DHerf1* [b]	1.505	*DSchump1* [b]	−0.547
	[1.020]		[0.988]		[0.845]
DEntry1 [b]	1.895 **	*DSpeat1* [b]	−0.814 **	*DHerf1* [b]	1.434
	[0.909]		[0.329]		[1.003]
DSchump2 [c]	0.087	*DSchump2* [c]	0.110	*DSpeat1* [b]	−0.614
	[0.661]		[0.116]		[0.468]
DHerf2 [c]	1.683 ***	*DHerf2* [c]	−2.268 *	*DEntry1* [b]	0.736
	[0.865]		[0.846]		[1.243]
DEntry2 [c]	0.203	*DSpeat2* [c]	0.242	*DSchump2* [c]	−0.105
	[0.928]		[0.328]		[0.782]

Table 7b (continued)

Regression 4		Regression 5		Regression 6	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
DumDe [d]	0.011	*DumDe* [d]	0.179 ***	*DHerf2* [c]	−2.275 *
	[0.104]		[0.100]		[0.862]
DumFr [d]	0.208 **	*DumFr* [d]	0.407 *	*DSpeat2* [c]	0.319
	[0.101]		[0.107]		[0.418]
DumUK [d]	0.208 **	*DumUK* [d]	0.423 *	*DEntry2* [c]	0.318
	[0.102]		[0.113]		[1.157]
Dum/t [d]	0.320 *	*Dum/t* [d]	0.420 *	*DumDe* [d]	0.188
	[0.111]		[0.112]		[0.115]
DumUS [d]	0.074	*DumUS* [d]	0.246 **	*DumFr* [d]	0.418 *
	[0.101]		[0.104]		[0.121]
				DumUK [d]	0.437 *
					[0.127]
				Dum/t [d]	0.421 *
					[0.113]
				DumUS [d]	0.256 **
R squared	0.155	R squared	0.203	R squared	0.204
Adj. R squared	0.115	Adj. R squared	0.165	Adj. R squared	0.157
F value	3.833	F value	5.312	F value	4.297

$n = 284$.
Source and notes: see Table 6.

are constituted by the measure of stability of the core of innovators (*SPEACORE*) and by the indicator of asymmetries (*HERF*) (in this last case, only for Japan).

(b) The characterization of a technological class as Schumpeter Mark I or Schumpeter Mark II is very similar across countries. If technological classes are grouped according to measures of Schumpeterian patterns of innovations, in all countries, most of them show similar patterns. Principal component analysis (see Table 3) shows that many of the classes which were included in the Schumpeter I and Schumpeter II groups are quite similar in all countries. Specifically, 19 technological classes are consistently in the Schumpeter Mark I camp: clothing and shoes (2), furniture (3), agriculture (4), chemical, analytical, physical processes (14), medical preparations (16), chemical processes for food and tobacco (20), machine tools (22), industrial automation (23), industrial machinery and equipment (24), railways and ships (28), material handling apparatus (29), civil engineering and infrastructure (30), mechanical engineering (32), mechanical and electric technologies (33), household electric appliances (34), lighting systems (35), measurement and control instruments (36), sports and toys (46) and the residual class 'others' (49). Conversely, 15 technological classes are consistently in the Schumpeter Mark II camp: gas, hydrocarbons and oil (6), organic chemicals (8), macromolecular compounds (9), biochemicals, bio- and genetic engineering (12), aircraft (27), engines, turbines and pumps (31), laser technology (37), optics and photography (38), computers (39), other office equipment (40), electronic components (42), telecommunications (44), multimedia systems (45), ammunition and weapons (47) and nuclear technology (48).

In sum, Schumpeter Mark I technological classes are to be found especially in the 'traditional' sectors, in the mechanical technologies, in instruments as well as in the white electric industry. Conversely, most of the chemical and electronic technologies are characterized by the Schumpeter Mark II model.

5. Country differences

The relevant role of technological imperatives and technological regimes does not completely wipe away differences among countries. Important differences persist as a consequence of country-specific effects related to the national systems of innovation and the specific histories of firms and industries. These differences concern some general features of the patterns of innovation across all technological classes in each country, the values of some indicators in specific technological classes, the relationships between the variables which define the Schumpeterian patterns of innovation and the patterns of innovation in particular technological classes.

5.1. General country-specific characteristics

The comparison of the average values of the various indicators for the European countries, Japan and the United States identifies some national specificities in the patterns of innovative activities (see Table 5). If one compares the USA, Japan and the four European countries considered together, Japan emerges as a rather concentrated (*C4*) and stable country (*SPEATOT*) as opposed to Europe. The United States and Europe show similar features, although Europe is on average less concentrated and stable than the United States.

If the comparison is made considering the individual European countries, Germany emerges as a typical Schumpeter Mark II country: high asymmetries, concentration and stability, limited role of new innovators and high relevance of large firms. Conversely, Italy exhibits a Schumpeter Mark I pattern, despite a very high concentration. Japan looks quite similar to Germany, although it has a very high value of innovative entry. The other countries fall in between these extremes. The USA is characterized by low degrees of concentration (*C4*) and asymmetry (*HERF*), low innovative entry (*ENTRY*), high degree of stability of the ranking of innovators within the core of companies which innovate continuously over time (*SPEACORE*): that is to say, innovative activities are widely diffused in a relatively stable group of innovators. The UK and France are quite similar, but the former country is characterized by a low stability of the ranking of innovators.

Differences can also be observed in the relationships between the various indicators in any individual country (Table 1). In particular (as was mentioned in Section 3.2), in the USA there is no correlation, and in Japan a negative one, between the variable *SPEATOT* and the measures of concentration (*C4* and *HERF*). Moreover, and different from the other countries, Japan is characterized by a low negative correlation between innovative entry (*ENTRY*) and concentration (*C4*) (significant at the 5% level) and asymmetries (*HERF*) (non-statistically significant, however).

5.2. Structural differences between technological classes

Some differences among Europe, the United States and Japan emerge also by looking at the correlations across countries of the various indicators for the 49 technological classes (Table 4).

In particular, major differences exist in the stability of the ranking of firms that innovate in both periods (1978–1985 and 1986–1991) (*SPEACORE*). This measure indicates how different the degree of competition in the 'core' group is across countries even for the same technological class.

Moreover, one observes very low values of the correlation coefficient between Japan and the other countries as it concerns the indicator of asymmetries (*HERF*).

Finally, the correlation coefficients for the size of innovating firms (*SIZE*) between the European countries are not particularly impressive.

5.3. The patterns of innovation in specific technological classes

Finally, specific technological classes behave differently in specific countries. These classes are: food and tobacco (1) (Schumpeter Mark I only in Germany and France), mining (5), inorganic chemicals (7) (Schumpeter Mark I only in the USA and Italy), new materials (10), adhesives, coating and synthetic resins (11), drugs (15) (Schumpeter Mark I in the USA and Italy), paper (17) (Schumpeter Mark II only in the USA and Italy), chemical treatments of fibers and paper (18) (Schumpeter Mark I only in

Table 8
Patterns of innovative activities and technological specialization: factors affecting revealed technological advantages (RTAW) of four countries [a]

Regression 1		Regression 2		Regression 3	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
Intercept	1.989 *	*Intercept*	1.750 *	*Intercept*	1.336 *
	[0.438]		[0.380]		[0.143]
HERF	2.200 *	*HERF*	1.980 *	*HERF*	1.941 *
	[0.514]		[0.474]		[0.489]
SPEATOT	−0.277	*ENTRYFIRM*	−0.479	*SPEATOT*	0.006
	[0.252]		[0.423]		[0.178]
ENTRYFIRM	−0.947	*SIZE*	−0.011 *	*SIZE*	−0.009 *
	[0.600]		[0.002]		[0.002]
SIZE	−0.010 *				
	[0.002]				
R squared	0.128	R squared	0.122	R squared	0.117
Adj. R squared	0.110	Adj. R squared	0.109	Adj. R squared	0.103
F value	7.001	F value	8.924	F value	8.441

Regression 4		Regression 5		Regression 6	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
Intercept	1.236 *	*Intercept*	2.250 *	*Intercept*	2.291 *
	[0.150]		[0.508]		[0.422]
HERF	2.634 *	*HERF*	2.913 *	*HERF*	2.936 *
	[0.479]		[0.493]		[0.4667]
SPEATOT	0.431 **	*SPEATOT*	0.039	*ENTRYFIRM*	−1.479 *
	[0.187]		[0.265]		[0.473]
SIZE	−0.007 *	*ENTRYFIRM*	−1.409 **	*SIZE*	−0.007 *
	[0.002]		[0.676]		[0.002]
DSchump1 [b]	0.329 *	*SIZE*	−0.007 *	*DSchump1* [b]	0.352 *
	[0.090]		[0.002]		[0.089]
DSchump2 [c]	−0.271 *	*DSchump1* [b]	0.353 *	*DSchump2* [c]	−0.284 *
	[0.087]		[0.090]		[0.086]
DumDe [d]	−0.065	*DSchump2* [c]	−0.284 *	*DumDe* [d]	−0.194
	[0.107]		[0.087]		[0.119]
DumFr [d]	0.109	*DumDe* [d]	−0.190	*DumFr* [d]	−0.011
	[0.098]		[0.122]		[0.105]
DumUK [d]	0.109	*DumFr* [d]	−0.006	*DumUK* [d]	−0.020
	[0.098]		[0.111]		[0.102]
		DumUK [d]	−0.013		
			[0.113]		
R squared	0.266	R squared	0.282	R squared	0.282
Adj. R squared	0.234	Adj. R squared	0.248	Adj. R squared	0.252
F value	8.449	F value	8.128	F value	9.189

Source and notes: see Table 6.

France and Italy), metallurgy (21), agricultural machinery (25), vehicles (26) (Schumpeter Mark I only in the USA and Japan), electrical devices and systems (41), and consumer electronics (43) (Schumpeter Mark I only in the UK and USA) (Table 3).

In sum, national specificities in the patterns of

Table 9
Patterns of innovative activities and technological specialization (spline function) (four European countries) [a]

Regression 1		Regression 2		Regression 3	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
Intercept	1.423 **	*Intercept*	1.670 *	*Intercept*	0.917 *
	[0.720]		[0.597]		[0.206]
HERF	2.999 *	*HERF*	3.081 *	*HERF*	2.853 *
	[0.660]		[0.647]		[0.637]
SPEATOT	0.222	*ENTRYFIRM*	−1.117	*SPEATOT*	0.408
	[0.361]		[0.679]		[0.259]
ENTRYFIRM	−0.702	*SIZE*	−0.001	*SIZE*	−0.000
	[0.957]		[0.004]		[0.004]
SIZE	−0.001	*DSchump1*	−0.239	*DSchump1*	0.945 *
	[0.004]		[0.942]		[0.356]
DSchump1	0.068	*DHerf1*	4.873 *	*DHerf1*	4.947 *
	[1.057]		[1.614]		[1.613]
DHerf1	4.661 *	*DEntry1*	0.604	*DSpeat1*	0.182
	[1.629]		[1.037]		[0.443]
DSpeat1	0.518	*DSize1*	−0.013 **	*DSize1*	−0.017 *
	[0.583]		[0.006]		[0.006]
DEntry1	1.224	*DSchump2*	0.846	*DSchump2*	0.339
	[1.394]		[0.759]		[0.296]
DSize1	−0.015 **	*DHerf2*	−2.211 **	*DHerf2*	−2.882 *
	[0.006]		[0.931]		[0.987]
DSchump2	1.111	*DEntry2*	−0.907	*DSpeat2*	0.264
	[0.899]		[0.887]		[0.381]
DHerf2	−2.097 **	*DSize2*	−0.005	*DSize2*	−0.005
	[1.059]		[0.005]		[0.005]
DSpeat2	−0.248				
	[0.529]				
DEntry2	−1.360				
	[1.246]				
DSize2	−0.005				
	[0.005]				
R squared	0.399	R squared	0.389	R squared	0.375
Adj. R squared	0.353	Adj. R squared	0.353	Adj. R squared	0.337
F value	8.596	F value	10.670	F value	10.018

Regression 4		Regression 5		Regression 6	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
Intercept	0.888 *	*Intercept*	1.340 ***	*Intercept*	1.856 *
	[0.206]		[0.781]		[0.633]
HERF	2.809 *	*HERF*	2.889 *	*HERF*	3.043 *
	[0.638]		[0.657]		[0.647]
SPEATOT	0.492 ***	*SPEATOT*	0.350	*ENTRYFIRM*	−1.393 ***
	[0.261]		[0.371]		[0.722]
SIZE	−0.000	*ENTRYFIRM*	−0.614	*SIZE*	−0.000
	[0.004]		[1.034]		[0.004]
DSchump1	1.088 *	*SIZE*	−0.000	*DSchump1*	0.345
	[0.359]		[0.004]		[0.945]
DHerf1	5.124 *	*DSchump1*	0.037	*DHerf1*	4.908 *
	[1.605]		[1.053]		[1.612]

Table 9 (continued)

Regression 4		Regression 5		Regression 6	
Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW	Independent variables	Dependent variable RTAW
DSpeat1	0.340	*DHerf1*	4.724 *	*DEntry1*	0.537
	[0.444]		[1.615]		[1.036]
DSize1	−0.019 *	*DSpeat1*	0.767	*DSize1*	−0.013 **
	[0.006]		[0.589]		[0.006]
DSchump2	0.328	*DEntry1*	1.495	*DSchump2*	0.840
	[0.298]		[1.392]		[0.758]
DHerf2	−2.706 *	*DSize1*	−0.017 *	*DHerf2*	−2.114 **
	[0.982]		[0.006]		[0.938]
DSpeat2	0.252	*DSchump2*	1.239	*DEntry2*	−0.841
	[0.380]		[0.895]		[0.889]
DSize2	−0.006	*DHerf2*	−1.884 ***	*DSize2*	−0.006
	[0.005]		[1.052]		[0.005]
DumDe	−0.062	*DSpeat 2*	−0.305	*DumDe*	−0.163
	[0.103]		[0.526]		[0.115]
DumFr	0.136	*DEntry2*	−1.517	*DumFr*	0.013
	[0.093]		[1.246]		[0.100]
DumUK	0.108	*DSize2*	−0.006	*DumUK*	−0.026
	[0.093]		[0.005]		[0.098]
		DumDe	−1.126		
			[0.116]		
		DumFr	0.092		
			[0.106]		
		DumUK	0.075		
			[0.109]		
R squared	0.395	R squared	0.422	R squared	0.403
Adj. R squared	0.349	Adj. R squared	0.366	Adj. R squared	0.357
F value	8.457	F value	7.632	F value	8.742

$n = 195$
Source and notes: see Table 6.

innovation do indeed exist. They emerge especially at the aggregate level, where one is able to identify 'Schumpeter Mark II' countries (Germany, Japan, and to a lesser extent the USA), as opposed to Italy, typically a 'Schumpeter Mark I' country.

Moreover, one can observe a major difference between Europe on the one hand and the USA and Japan on the other in the relationship between concentration (*HERF*) and stability. (*SPEATOT*) Similarly, the variables measuring respectively the stability in the ranking of continuous innovators (*SPEACORE*) and the size of innovating firms (*SIZE*) behave quite differently across countries. Finally, in Japan one observes differences from the other countries relatively more frequently as compared to other nations. However, on the whole these data and indicators do not suffice in identifying clear and systematic national specificities.

6. Patterns of innovative activities and countries' technological specializations

Finally, in this paper we inquire whether any relationship exists between the variables that define the sectoral patterns of innovative activities on the one hand and international technological specialization on the other. This has been a long debated topic in the economics of technological change. In particular, within the context of the debate on the 'Schumpeterian hypotheses' about the role of firm size and market concentration in influencing technological performance, attention was focused on the relationships between variables such as concentration of innovative activities and size of innovative firms and various measures of technological performance, including technological specialization. Earlier results (Pavitt and Patel, 1992) failed however to identify systematic relationships between these variables. Two reasons may be at the base of the lack of a significant relationship. First, such absence of correlation may be due to the fact that the variables which have an impact on international technological performance are not the 'traditional' Schumpeterian variables related to concentration or firm size. Second, the relationship may be different according to the type of technological class.

Here, we explore these issues. The first hypothesis to be tested is whether international technological specialization is significantly associated with variables measuring the patterns of innovative activities other than concentration and firm size. More specifically, we focus on the role played by the variables measuring the degree of 'stability' ('creative accumulation') or 'dynamism' ('creative destruction') in the organization of innovative activity, in terms of the degree of change in the hierarchy of the innovators and of the relevance of new innovators. Technological specialization may be associated with the existence of a wide pool of potential innovators, who compete by exploiting latent technological opportunities and on these grounds introduce a variety of technological advances. In this case, one would expect technological specialization to be positively related to high rates of entry of new innovators and low stability in the ranking of innovators. Conversely, technological specialization may be linked to systematic and continuous processes of accumulation of technological capabilities at the firm level. In this case, technological specialization would be correlated with a high degree of stability in the ranking of innovators and low rates of technological entry.

Asymmetries and concentration of innovative activities are likely to be low in the first case and high in the second case. However, there is no necessary relationship between the degree of stability or dynamism (as measured by the role of new innovators and the stability of the hierarchy of innovators) on the one hand and concentration and asymmetries on the other. In particular, creative accumulation may well be compatible with low innovative concentration, if innovative activities are generated by a large number of firms that innovate continuously and compete fiercely.

The second hypothesis to be tested is whether the relationships between the patterns of innovation and international technological specialization differ across technologies. In this paper, we examine whether the 'creative destruction model' is positively associated with technological performance in Schumpeter Mark I technological classes and negatively in Schumpeter Mark II technological classes.

In the following exercises, the dependent variable is the international specialization of a country in terms of revealed technological advantages for the period 1986–1991 (*RTAW*). *RTAW* is the ratio between the world patents share of a country in a given technological class and the world patents share of that country in all technological classes. The independent variables are the measures used to identify the Schumpeterian patterns of innovation: asymmetries (*HERF*), stability (SPEATOT) and the role of new innovators (*ENTRY*). [8] As it concerns this latter measure, notice that the variable *ENTRY* that we have been using so far to measure the role of technological entry is negatively correlated with the indexes of revealed technological advantages (*RTAW*), since the same magnitude appears respectively in the numerator of *RTAW* and in the denominator of *ENTRY*: the number of patents held by country i in technological class j in the period 1986–1991. To eliminate this spurious correlation, we substituted the variable *ENTRY* with the variable *ENTRYFIRM*, defined as the number of firms applying for a patent for the first time in the period

[8] In another set of regressions, the variable *C4* was used instead of *HERF* as a measure of concentration and the variable *SPEACORE* was employed instead of *SPEATOT*. In both cases, no significant difference in the performance of the alternative measures was found. Therefore, in what follows we shall refer only to the results obtained by using *HERF* and *SPEATOT*.

1986–1991 as a percentage of the total number of firms that applied for a patent in the same period.

Given the characteristics of the data, we cannot say much about the direction of causation between technological specialization and the measures of the patterns of innovation. We cannot claim unambiguously, for example, that innovative entry generates technological specialization or that it is the latter that leads to higher innovative entry. Similarly, we do not claim that the measures of the sectoral patterns of innovation can 'explain' revealed technological advantages. An explanation of the latter is very likely to involve additional variables and a dynamic analysis that we cannot do with our data. For the purposes of this paper, we interpret the results of the regressions simply as evidence of the existence or absence of correlation between the variables.

The first set of regressions performs quite badly (Table 6). The measure of asymmetries (*HERF*) is significant and has a positive sign, but the other variables are not significant. R^2 is extremely low. If either the variable *ENTRYFIRM* or the variable *SPEATOT* are excluded in order to overcome a possible problem of multicollinearity, only the variable *ENTRYFIRM* becomes significant with a negative sign, when *SPEATOT* is excluded.

The inclusion of country and sector (for Schumpeter Mark I and Schumpeter Mark II technological classes) fixed effects improves only moderately the overall results. The variable *HERF* remains positive and significant, the variable *SPEATOT* becomes significant with a positive sign and *ENTRYFIRM* becomes significant with a negative sign (when *SPEATOT* is excluded).

In order to control for shifts in the slope of the independent variables in Schumpeter Mark I and Schumpeter Mark II technological classes, we ran a restricted regression on a spline function (Table 7). Results confirm basically the previous findings. However, they show that, in Schumpeter Mark I technological classes, revealed technological advantages are associated with a relatively lower stability of the ranking of innovators or with a higher role of new innovators. Conversely, Schumpeter Mark II technological classes are characterized by lower degrees of asymmetries. The inclusion of country fixed effects does not change these conclusions and improves the fit only slightly.

Finally, we ran a further series of regressions including also the measure of the size of the innovative firms (*SIZE*) for the four European countries for which this measure is available (Table 8).

The measure of asymmetries (*HERF*) is still significant with a positive sign and *SIZE* is significant and negative, while the other variables (stability of the hierarchy of innovators, *SPEATOT* and the role of new innovators, *ENTRYFIRM*) lose their significance. The inclusion of sector and country fixed effects improves the overall results, although the dummy variables controlling for the country effects are not significant. Asymmetries (*HERF*) and the size of the innovators (*SIZE*) remain significant with, respectively, a positive and a negative sign. The variable measuring the role of new innovators (*ENTRYFIRM*) becomes significant and negative. The stability of the hierarchy of innovators (*SPEATOT*) is positive and significant when *ENTRYFIRM* is excluded from the specification.

Regressions on the spline function confirm again the previous results (Table 9). In Schumpeter Mark I technological classes, the dummies for asymmetries (*D1HERF*) and for the size of the innovators (*D1 SIZE*) are significant with, respectively, a positive and a negative sign. Conversely, in Schumpeter Mark II technological classes, the dummy for asymmetries (*D2HERF*) is significant and negative.

In sum, these results indicate that technological specialization is associated positively with asymmetries in firms' innovative activities and with stability in the ranking of innovators; negatively with the role of new innovators and the size of the innovating firms. However, these relationships are somewhat different across technological classes. In Schumpeter Mark I sectors, technological advantages are related to high degrees of asymmetries in a population of firms of small economic size, relatively higher rates of technological entry or relatively lower stability of the ranking of innovators. That is to say, technological specialization in these technological classes is higher when the entry of new innovators is complemented by the presence of core important (but small in terms of economic size) innovators. In Schumpeter Mark II sectors, technological advantages are linked to the existence of a stable but competitive core of systematic and persistent innovators.

In any case, these results clearly indicate that other variables are needed in order to explain technological specialization and that our understanding on this issue is still very poor.

7. Conclusions

This paper has examined the patterns of innovative activities at the technological and country levels. The main findings are the following:

(a) As expected, the patterns of innovative activities differ systematically across technological classes.

(b) These patterns however are remarkably similar across countries for each technological class.

(c) This result suggests that *technological imperatives* and technology-related factors (such as *technological regimes*, defined in terms of opportunity, appropriability, cumulativeness and knowledge-base features) play a major (albeit of course not unique) role in determining the specific pattern of innovative activities of a technological class across countries.

(d) Two groups of technological classes have been identified: *Schumpeter Mark I* and *Schumpeter Mark II* classes. In these two groups innovative activities are structured and organized in different ways. The first represents a *widening* pattern: concentration of innovative activities is low, innovators are of small economic size, stability in the ranking of innovators is low and turbulence of innovators is high. The second represents a *deepening* pattern: concentration of innovative activities is higher than in the first group, innovators are of larger economic size, stability in the ranking of innovators is greater, and turbulence is lower. The former group comprises mechanical technologies and traditional sectors, while the latter includes chemicals and electronics.

(e) Within the major constraints identified by technological imperatives and technological regimes, *country-specific factors* introduce differences across countries in the pattern of innovative activities for a specific technological class. These country-specific factors may range from the peculiar history and industrial development of a country to the level and type of competences and competitiveness of specific firms within the industrial structure, and from the type and extent of public policy to the relevant features of institutions and national systems of innovation. A more precise identification of the national specificities in the sectoral patterns of innovative activities however is likely to require a richer set of indicators than that used in this paper.

(f) A final result regards the relationship between the specific features of the patterns of innovative activities and *international technological specialization*. Technological advantages appear in general to be linked to higher degrees of asymmetries among innovators, higher stability of the ranking of innovators, smaller economic size of the innovating firms and lower entry rates of new innovators. In other words, international technological specialization is associated with the existence of a stable core of persistently asymmetric innovators, that are however relatively small in economic terms.

(g) This general conclusion is highly enriched if one introduces the technological specificities of groups of sectors. In Schumpeter Mark I (widening) technological classes, international technological specialization is associated with relatively higher degrees of asymmetries among innovators and innovative turbulence (as well as smaller firm size), while in Schumpeter Mark II (deepening) technological classes, international technological specialization is linked to the existence of a stable but competitive core of persistent innovators.

In the examination of the patterns of innovative activities at the technological and country levels, this paper has opened up a set of additional conceptual issues and empirical questions that need further research in various directions. They include a more sophisticated and formal analysis of the relationship between technological regimes and patterns of innovative activities; the analysis of the role of institutions in affecting a specific sectoral pattern of innovative activities across countries, the possible presence of a small country effect, and innovative entry and exit and the type of changes in Schumpeterian patterns occurring during a technology and an industry life cycle.

Acknowledgements

We thank Francesco Lissoni for his help and comments, Monica Coppi and Monica Soana for skillful research assistance and two anonymous referees for their comments which greatly contributed to improve on an earlier version of this paper. This paper has benefitted from the contribution of the Italian CNR (Project no. 92.01885.10-115.19189) and of the Human Capital and Mobility Programme of the European Union (Contract no. 920002).

Appendix

Table A.1
Technology classification

1	Food, Tobacco	26	Vehicles, Motorcycles, other Land vehicles
2	Clothing, Shoes	27	Aircraft
3	Furniture	28	Railways, Ships
4	Agriculture	29	Materials handling apparatus
5	Mining	30	Civil engineering, Infrastructure
6	Gas, Hydrocarbons, Oil	31	Engines, Turbines, Pumps
7	Inorganic chemicals	32	Mechanical engineering
8	Organic chemicals	33	Mechanical and Electric technologies
9	Macromolecular compounds	34	Household electric appliances
10	New materials	35	Lighting systems
11	Adhesives, Coatings, Synthetic resins	36	Measurement and Control instruments
12	Biochemicals, Bio- and Genetic engineering	37	Laser technology
13	Miscellaneous chemical compounds	38	Optics and Photography
14	Chemical, Analytical, Physical processes	39	Computers, Data processing systems
15	Drugs	40	Other office equipment
16	Medical preparations	41	Electrical devices and systems
17	Natural and Artificial fibres, Paper	42	Electronic components
18	Chemical treatment of natural or artificial fibres and paper	43	Consumer electronics
19	Agricultural chemicals	44	Telecommunications
20	Chemical processes for food and tobacco	45	Multimedia systems
21	Metallurgy	46	Decorative and Figurative arts, Sports, Toys
22	Machine tools	47	Ammunition, Weapons
23	Industrial automation	48	Nuclear technology
24	Industrial machinery and Equipment	49	Others
25	Agricultural machinery		

Table A.2
Concentration index (*C4*) by technological classes and country

CODE	USA	JAP	GER	FR	UK	IT	Av	Std
1	34.7	30.5	32.3	19.2	70.7	38.4	37.6	17.5
2	27.5	80.4	22.6	30.1	16.1	58.7	39.2	24.9
3	12.6	22.0	9.2	18.0	10.2	15.0	14.5	4.9
4	19.4	19.5	16.0	16.2	16.5	15.9	17.2	1.7
5	36.7	37.1	16.3	57.3	23.3	60.0	38.4	17.6
6	48.3	29.0	30.6	48.6	51.6	51.9	43.3	10.6
7	21.6	12.0	39.5	40.8	42.1	36.4	32.1	12.3
8	19.4	19.4	68.8	32.8	53.9	25.5	36.6	20.3
9	33.8	20.3	73.9	42.7	56.5	52.8	46.6	18.7
10	23.5	19.8	24.4	32.2	28.9	31.9	26.8	5.0
11	26.2	22.5	63.7	27.5	44.8	36.7	36.9	15.5
12	12.8	20.8	41.9	36.3	39.3	39.2	31.7	12.0
13	68.9	50.9	81.1	41.9	89.1	60.7	65.4	17.9
14	15.5	9.2	20.6	21.5	30.4	14.2	18.6	7.3
15	13.9	20.1	31.6	–	46.5	18.8	26.2	13.1
16	13.1	33.2	30.9	15.0	20.5	20.9	22.3	8.2
17	32.3	32.5	20.5	22.1	24.2	33.0	27.4	5.8
18	26.9	25.4	48.5	19.7	32.3	20.6	28.9	10.6
19	25.5	31.2	69.4	42.6	46.6	44.7	43.3	15.2
20	27.8	20.2	25.4	13.6	43.5	29.2	26.6	10.1
21	18.5	28.2	21.5	19.4	23.5	19.8	21.8	3.6
22	20.5	22.7	31.9	31.1	25.2	36.8	28.0	6.2
23	18.0	60.8	17.0	17.8	21.6	19.2	25.7	17.3
24	8.5	11.8	12.2	11.9	9.9	17.5	12.0	3.0
25	82.8	37.5	43.0	51.1	36.1	41.4	48.7	17.6
26	29.7	38.7	25.0	39.4	37.0	38.6	34.7	6.0
27	57.0	48.7	58.3	66.9	56.0	58.8	57.6	5.8
28	18.2	45.2	25.1	32.4	18.1	36.3	29.2	10.7
29	10.7	13.2	10.0	7.8	14.4	13.6	11.6	2.5
30	12.1	19.1	7.7	10.7	6.8	15.1	11.9	4.6
31	21.7	36.5	38.1	39.2	38.9	38.3	35.5	6.8
32	17.1	30.3	12.9	24.5	31.5	20.6	22.8	7.4
33	19.2	21.4	12.5	20.0	15.6	24.3	18.8	4.2
34	14.2	47.0	22.3	36.5	15.9	25.3	26.9	12.7
35	34.6	53.0	49.3	44.6	37.8	35.4	42.4	7.7
36	11.5	23.2	28.9	20.3	12.5	19.4	19.3	6.6
37	33.7	48.4	47.9	53.1	45.6	63.0	48.6	9.6
38	41.6	45.1	50.3	36.0	29.1	38.3	40.1	7.4
39	47.8	40.9	54.0	34.4	22.4	63.9	43.9	14.7
40	62.4	40.2	49.4	38.5	44.5	92.0	54.5	20.3
41	22.1	33.5	38.3	18.6	17.5	18.1	24.7	8.9
42	34.7	53.2	52.4	42.9	31.6	49.0	44.0	9.2
43	29.4	47.4	51.1	44.5	31.5	41.8	40.9	8.8
44	40.3	58.8	61.4	35.2	35.9	58.7	48.4	12.5
45	55.7	63.9	68.9	60.9	79.4	91.7	70.1	13.3
46	13.7	17.4	12.0	27.4	10.2	19.5	16.7	6.2
47	29.7	63.9	55.7	45.4	46.0	35.1	46.0	12.6
48	80.0	64.3	54.1	75.4	66.2	85.7	70.9	11.6
49	19.1	40.5	22.1	15.9	16.3	19.6	22.2	9.2

Av = averages; Std = standard deviation.
Source: EPO-CESPRI database.

Table A.3
Herfindahl index of asymmetry (*HERF*) by technological class and country

CODE	USA	JAP	GER	FR	UK	IT	Av	Std
1	0.05	0.04	0.04	0.02	0.38	0.05	0.10	0.14
2	0.03	0.48	0.02	0.04	0.02	0.26	0.14	0.19
3	0.01	0.03	0.01	0.01	0.01	0.02	0.01	0.01
4	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.00
5	0.05	0.05	0.02	0.10	0.03	0.11	0.06	0.04
6	0.09	0.03	0.04	0.11	0.09	0.08	0.07	0.03
7	0.02	0.01	0.05	0.08	0.07	0.05	0.05	0.03
8	0.02	0.02	0.15	0.04	0.11	0.03	0.06	0.06
9	0.04	0.02	0.19	0.07	0.15	0.10	0.10	0.06
10	0.02	0.02	0.03	0.05	0.03	0.04	0.03	0.01
11	0.03	0.02	0.13	0.03	0.12	0.07	0.07	0.05
12	0.01	0.02	0.06	0.05	0.05	0.05	0.04	0.02
13	0.27	0.16	0.38	0.07	0.61	0.13	0.27	0.20
14	0.01	0.01	0.02	0.02	0.04	0.01	0.02	0.01
15	0.01	0.02	0.04	0.04	0.07	0.02	0.03	0.02
16	0.01	0.04	0.06	0.01	0.02	0.02	0.03	0.02
17	0.05	0.04	0.02	0.02	0.02	0.04	0.03	0.01
18	0.03	0.03	0.07	0.02	0.04	0.02	0.04	0.02
19	0.02	0.06	0.18	0.08	0.09	0.09	0.09	0.05
20	0.03	0.02	0.03	0.01	0.11	0.04	0.04	0.04
21	0.02	0.03	0.02	0.02	0.03	0.03	0.02	0.01
22	0.02	0.03	0.04	0.04	0.03	0.06	0.04	0.01
23	0.02	0.23	0.01	0.02	0.02	0.02	0.05	0.09
24	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
25	0.44	0.06	0.09	0.12	0.06	0.06	0.14	0.15
26	0.03	0.06	0.03	0.05	0.05	0.08	0.05	0.02
27	0.15	0.10	0.13	0.25	0.14	0.13	0.15	0.05
28	0.02	0.07	0.03	0.04	0.02	0.07	0.04	0.02
29	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00
30	0.01	0.02	0.00	0.01	0.00	0.01	0.01	0.00
31	0.02	0.05	0.07	0.05	0.06	0.06	0.05	0.02
32	0.01	0.03	0.01	0.02	0.03	0.02	0.02	0.01
33	0.02	0.02	0.01	0.02	0.01	0.03	0.02	0.01
34	0.01	0.08	0.02	0.04	0.01	0.03	0.03	0.03
35	0.05	0.11	0.08	0.09	0.05	0.05	0.07	0.03
36	0.01	0.02	0.04	0.02	0.01	0.02	0.02	0.01
37	0.04	0.08	0.14	0.10	0.10	0.12	0.10	0.03
38	0.06	0.08	0.08	0.06	0.04	0.05	0.06	0.02
39	0.14	0.06	0.15	0.05	0.02	0.15	0.10	0.06
40	0.12	0.07	0.09	0.05	0.09	0.49	0.15	0.17
41	0.02	0.03	0.08	0.02	0.01	0.02	0.03	0.03
42	0.06	0.09	0.19	0.07	0.05	0.16	0.10	0.06
43	0.03	0.08	0.08	0.08	0.04	0.07	0.06	0.02
44	0.05	0.11	0.23	0.05	0.04	0.11	0.10	0.07
45	0.16	0.13	0.19	0.16	0.25	0.39	0.21	0.09
46	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
47	0.03	0.24	0.12	0.07	0.06	0.06	0.10	0.08
48	0.37	0.18	0.12	0.22	0.15	0.20	0.21	0.09
49	0.02	0.06	0.02	0.02	0.02	0.02	0.03	0.02

Source: EPO-CESPRI database.

Table A.4
Size of the innovating firms (*SIZE*) by technological class and country

CODE	GER	FRA	UK	IT	Av	Std
1	54.3	29.5	81.2	23.2	47.1	26.4
2	37.0	25.0	25.3	1.5	22.2	14.9
3	38.6	38.5	17.6	10.4	26.3	14.5
4	31.3	14.4	15.8	6.1	16.9	10.5
5	46.3	53.1	16.9	42.9	39.8	15.8
6	59.6	60.0	66.2	70.9	64.2	5.4
7	66.8	60.4	61.8	47.7	59.2	8.1
8	82.8	37.9	75.4	54.1	62.5	20.5
9	90.6	57.5	74.5	65.7	72.1	14.2
10	64.9	57.9	57.1	45.1	56.3	8.2
11	73.5	47.8	65.5	47.8	58.7	12.9
12	60.1	33.5	44.4	52.9	47.7	11.4
13	32.8	61.3	94.5	35.7	56.1	28.7
14	56.4	47.7	48.3	23.3	43.9	14.3
15	59.3	37.8	65.6	29.6	48.1	17.1
16	25.7	29.2	25.2	8.6	22.2	9.2
17	59.2	25.9	39.3	21.0	36.3	17.1
18	71.2	27.5	55.9	18.6	43.3	24.5
19	80.5	49.2	57.8	29.8	54.3	21.0
20	61.7	35.3	55.7	29.2	45.5	15.6
21	59.2	40.0	40.2	33.7	43.3	11.0
22	49.7	63.8	37.8	36.8	47.1	12.6
23	53.7	42.3	36.1	15.5	36.9	16.0
24	51.4	41.6	35.3	25.0	38.3	11.1
25	68.2	34.7	30.1	17.2	37.6	21.7
26	53.2	66.2	43.9	48.1	52.8	9.7
27	37.0	18.6	35.1	35.3	31.5	8.6
28	35.2	36.6	32.7	38.1	35.6	2.3
29	41.7	34.6	32.9	21.2	32.6	8.5
30	42.9	33.8	19.5	12.1	27.1	13.9
31	42.4	69.2	42.1	51.3	51.2	12.7
32	56.3	55.5	43.4	31.9	46.8	11.6
33	49.7	42.8	31.6	29.3	38.3	9.6
34	32.5	42.9	23.9	14.6	28.5	12.1
35	50.4	39.1	28.9	25.0	35.8	11.4
36	41.9	35.1	45.2	37.9	40.0	4.5
37	60.3	73.9	60.8	42.6	59.4	12.8
38	54.7	57.8	62.3	35.8	52.6	11.6
39	75.5	54.1	43.0	27.1	49.9	20.3
40	77.5	45.0	45.8	68.4	59.2	16.3
41	62.1	39.7	44.2	34.1	45.0	12.1
42	23.4	45.3	54.4	22.3	36.4	16.0
43	47.2	48.9	48.7	21.7	41.6	13.3
44	24.2	30.4	67.0	52.5	43.5	19.8
45	57.8	65.2	64.7	100.0	71.9	19.0
46	32.9	23.9	15.5	3.7	19.0	12.4
47	45.4	24.6	51.4	27.0	37.1	13.3
48	45.9	80.0	52.9	64.3	60.8	14.9
49	40.1	37.9	33.7	10.9	30.6	13.4

Source: EPO-CESPRI database.

Table A.5
Stability in the hierarchy of innovators (*SPEATOT*)

CODE	USA	JAP	GER	FR	UK	ITA	Av	Std
1	−0.30	−0.20	−0.30	−0.40	−0.30	−0.30	−0.30	0.10
2	−0.50	−0.40	−0.30	−0.50	−0.80	−0.50	−0.50	0.20
3	−0.60	−0.60	−0.30	−0.60	−0.70	−0.60	−0.60	0.10
4	−0.70	−0.60	−0.60	−0.70	−0.60	−0.80	−0.70	0.10
5	−0.20	−0.20	−0.20	−0.30	−0.40	−0.80	−0.40	0.20
6	−0.20	−0.10	0.10	−0.20	−0.20	−0.40	−0.20	0.10
7	−0.20	−0.10	−0.20	−0.30	−0.30	−0.50	−0.20	0.10
8	0.20	0.50	0.40	0.00	0.10	0.10	0.20	0.20
9	0.10	0.30	0.00	−0.10	−0.20	0.00	0.00	0.20
10	−0.10	0.10	0.00	−0.30	−0.20	−0.40	−0.20	0.20
11	0.00	0.20	−0.10	−0.30	−0.30	−0.40	−0.20	0.20
12	0.10	0.20	0.00	−0.20	−0.30	−0.30	−0.10	0.20
13	−0.30	−0.30	−0.20	−0.40	0.00	0.70	−0.10	0.40
14	−0.20	0.10	−0.20	−0.30	−0.40	−0.50	−0.20	0.20
15	0.10	0.20	0.10	−0.20	0.00	−0.10	0.00	0.10
16	−0.20	0.00	−0.20	−0.30	−0.40	−0.60	−0.30	0.20
17	−0.10	0.00	−0.20	−0.30	−0.40	0.10	−0.20	0.20
18	0.00	0.10	0.00	−0.30	−0.20	−0.70	−0.20	0.30
19	−0.30	−0.10	−0.20	−0.40	−0.20	−0.60	−0.30	0.20
20	−0.20	−0.20	−0.20	−0.60	−0.40	−0.80	−0.40	0.20
21	−0.10	0.10	0.00	0.00	−0.10	−0.40	−0.10	0.20
22	−0.20	−0.10	−0.30	−0.30	−0.40	−0.40	−0.30	0.10
23	−0.30	−0.10	−0.10	−0.50	−0.40	−0.50	−0.30	0.20
24	−0.20	−0.10	−0.10	−0.40	−0.40	−0.50	−0.30	0.20
25	−0.40	−0.80	0.10	−0.30	−0.50	−0.70	−0.40	0.30
26	−0.30	0.20	0.00	−0.20	−0.40	−0.40	−0.20	0.20
27	−0.20	−0.20	−0.10	0.20	−0.20	−0.70	−0.20	0.30
28	−0.70	−0.10	−0.30	−0.50	−0.60	−0.40	−0.40	0.20
29	−0.20	−0.10	−0.20	−0.50	−0.50	−0.50	−0.30	0.20
30	−0.50	−0.30	−0.20	−0.50	−0.50	−0.60	−0.40	0.20
31	−0.20	0.00	−0.10	−0.20	−0.30	−0.40	−0.20	0.20
32	−0.20	0.00	−0.10	−0.20	−0.40	−0.50	−0.30	0.20
33	−0.30	−0.20	−0.20	−0.20	−0.60	−0.70	−0.40	0.20
34	−0.40	−0.30	−0.20	−0.30	−0.50	−0.40	−0.40	0.10
35	−0.40	−0.20	−0.40	−0.70	−0.70	−0.50	−0.50	0.20
36	−0.20	0.10	−0.10	−0.20	−0.40	−0.40	−0.20	0.20
37	0.00	0.30	0.00	−0.20	−0.20	0.20	0.00	0.20
38	−0.10	0.20	0.00	−0.10	−0.20	−0.30	−0.10	0.20
39	−0.30	0.30	−0.10	−0.20	−0.40	−0.30	−0.20	0.20
40	−0.10	0.30	−0.10	−0.40	−0.50	0.00	−0.10	0.30
41	−0.20	0.20	0.00	−0.10	−0.30	−0.30	−0.10	0.20
42	0.00	0.10	0.20	−0.20	−0.30	−0.20	−0.10	0.20
43	−0.30	0.10	−0.10	−0.30	−0.40	−0.30	−0.20	0.20
44	−0.20	0.00	0.10	−0.10	−0.20	0.10	−0.10	0.10
45	−0.20	0.10	−0.50	−0.20	0.00	0.80	0.00	0.40
46	−0.50	−0.30	−0.50	−0.60	−0.70	−0.70	−0.60	0.10
47	−0.20	−0.40	0.00	−0.10	−0.50	−0.40	−0.30	0.20
48	−0.30	0.00	−0.20	0.10	−0.30	0.00	−0.10	0.20
49	−0.50	−0.40	−0.40	−0.50	−0.30	−0.40	−0.40	0.10

Source: EPO-CESPRI database.

Table A.6
Stability in the hierarchy of persistent innovators (*SPEACORE*)

CODE	USA	JAP	GER	FR	UK	IT	Av	Std
1	0.7	0.5	0.39	0.02	0.83	0.17	0.43	0.30
2	0.6	0.8	0.34	0.48	0.00	1.00	0.54	0.35
3	0.3	−0.7	0.26	0.54	0.00	0.20	0.09	0.42
4	−0.4	1.0	0.00	0.35	0.24	0.00	0.20	0.47
5	0.4	0.6	0.29	0.25	0.33	0.00	0.32	0.20
6	0.7	0.5	0.61	0.26	0.35	0.35	0.46	0.18
7	0.6	0.3	0.75	0.67	0.50	0.32	0.53	0.18
8	0.7	0.8	0.70	0.48	0.78	0.48	0.66	0.14
9	0.7	0.7	0.56	0.55	0.57	0.86	0.65	0.12
10	0.5	0.5	0.54	0.61	0.46	0.24	0.47	0.13
11	0.6	0.6	0.83	0.59	0.35	0.43	0.58	0.17
12	0.5	0.4	0.78	0.80	0.74	0.45	0.62	0.17
13	0.5	0.5	0.90	0.97	0.68	0.89	0.74	0.21
14	0.6	0.6	0.58	0.59	0.73	0.20	0.55	0.18
15	0.6	0.5	0.77	0.54	0.49	0.09	0.50	0.23
16	0.4	0.5	0.51	0.51	0.38	0.37	0.45	0.07
17	0.4	0.6	0.22	0.37	0.43	0.71	0.46	0.18
18	0.6	0.6	0.60	0.38	0.44	−0.33	0.39	0.37
19	0.4	0.5	0.66	0.63	0.51	−1.00	0.28	0.64
20	0.5	0.4	0.53	−0.05	0.48	−1.00	0.15	0.60
21	0.6	0.6	0.62	0.57	0.65	−0.01	0.50	0.26
22	0.4	0.4	0.59	0.03	0.53	−0.50	0.25	0.42
23	0.5	0.7	0.52	0.51	0.58	0.34	0.52	0.11
24	0.6	0.6	0.56	0.53	0.36	0.48	0.52	0.09
25	0.7	–	0.31	0.33	0.48	1.00	0.57	0.29
26	0.5	0.7	0.57	0.57	0.29	0.23	0.48	0.18
27	0.6	1.0	0.49	0.84	0.14	0.00	0.51	0.39
28	0.4	0.4	0.40	0.33	0.07	0.95	0.42	0.29
29	0.4	0.6	0.48	0.29	0.16	0.42	0.40	0.16
30	0.4	0.3	0.41	0.48	0.29	0.57	0.40	0.12
31	0.6	0.7	0.62	0.47	0.52	0.58	0.59	0.10
32	0.5	0.4	0.40	0.57	0.44	0.80	0.52	0.15
33	0.5	0.6	0.50	0.61	0.27	0.27	0.45	0.15
34	0.3	0.8	0.72	0.62	0.36	0.50	0.55	0.22
35	0.5	0.1	0.68	0.00	0.27	−1.00	0.09	0.59
36	0.6	0.6	0.64	0.64	0.59	0.53	0.59	0.04
37	0.6	0.8	0.06	0.39	0.84	0.71	0.57	0.29
38	0.6	0.6	0.57	0.43	0.72	0.37	0.55	0.13
39	0.6	0.7	0.75	0.23	0.58	1.00	0.64	0.25
40	0.7	0.7	0.65	0.41	0.63	1.00	0.68	0.19
41	0.6	0.7	0.49	0.42	0.62	0.28	0.52	0.15
42	0.6	0.6	0.64	0.51	0.54	0.46	0.55	0.07
43	0.5	0.7	0.73	0.21	0.43	0.77	0.56	0.22
44	0.6	0.7	0.65	0.28	0.58	0.66	0.57	0.15
45	0.8	0.5	1.00	0.00	0.00	1.00	0.55	0.46
46	0.5	0.2	0.26	0.60	0.77	0.19	0.42	0.24
47	0.3	–	0.62	0.83	0.62	0.04	0.48	0.31
48	0.8	0.5	0.82	0.41	0.50	0.00	0.51	0.30
49	0.5	0.8	0.40	0.33	0.23	0.61	0.49	0.22

Source: EPO-CESPRI database.

Table A.7
Entry of new innovators (*ENTRY*)

CODE	USA	JAP	GER	FR	UK	IT	Av	Std
1	0.2	0.6	0.4	0.7	0.2	0.6	0.4	0.2
2	0.5	0.3	0.6	0.5	0.9	0.4	0.5	0.2
3	0.8	0.8	0.6	0.8	0.8	0.8	0.8	0.1
4	0.8	0.9	0.7	0.8	0.7	0.9	0.8	0.1
5	0.3	0.7	0.6	0.4	0.6	1.0	0.6	0.3
6	0.1	0.4	0.2	0.3	0.2	0.6	0.3	0.2
7	0.3	0.5	0.3	0.4	0.4	0.8	0.5	0.2
8	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.1
9	0.1	0.2	0.1	0.2	0.2	0.3	0.2	0.1
10	0.3	0.4	0.3	0.3	0.4	0.8	0.4	0.2
11	0.2	0.3	0.1	0.5	0.4	0.8	0.4	0.2
12	0.3	0.3	0.1	0.4	0.4	0.5	0.3	0.1
13	0.3	0.4	0.1	0.6	0.1	0.6	0.3	0.2
14	0.3	0.4	0.4	0.4	0.4	0.8	0.4	0.2
15	0.3	0.3	0.2	0.3	0.2	0.5	0.3	0.1
16	0.4	0.4	0.4	0.5	0.5	0.8	0.5	0.2
17	0.3	0.4	0.5	0.5	0.7	0.4	0.5	0.1
18	0.3	0.4	0.2	0.6	0.3	0.9	0.5	0.3
19	0.5	0.6	0.2	0.5	0.3	0.9	0.5	0.2
20	0.4	0.7	0.5	0.8	0.5	0.9	0.6	0.2
21	0.3	0.3	0.3	0.3	0.4	0.7	0.4	0.2
22	0.4	0.5	0.5	0.5	0.7	0.7	0.5	0.1
23	0.4	0.2	0.4	0.5	0.6	0.7	0.5	0.2
24	0.3	0.4	0.3	0.5	0.4	0.7	0.4	0.1
25	0.1	1.0	0.1	0.3	0.6	0.7	0.5	0.3
26	0.3	0.2	0.2	0.3	0.3	0.5	0.3	0.1
27	0.3	0.8	0.4	0.2	0.4	0.9	0.5	0.3
28	0.8	0.4	0.4	0.6	0.7	0.7	0.6	0.2
29	0.4	0.5	0.4	0.6	0.6	0.7	0.5	0.1
30	0.6	0.6	0.4	0.6	0.7	0.8	0.6	0.1
31	0.2	0.2	0.2	0.2	0.3	0.5	0.3	0.1
32	0.3	0.4	0.4	0.3	0.4	0.7	0.4	0.2
33	0.5	0.4	0.4	0.3	0.6	0.8	0.5	0.2
34	0.6	0.5	0.3	0.5	0.7	0.7	0.6	0.2
35	0.6	0.4	0.4	0.9	0.8	0.9	0.7	0.2
36	0.3	0.3	0.2	0.4	0.4	0.6	0.4	0.1
37	0.3	0.4	0.4	0.5	0.5	0.5	0.4	0.1
38	0.1	0.2	0.2	0.3	0.3	0.5	0.3	0.1
39	0.2	0.1	0.3	0.3	0.5	0.5	0.3	0.2
40	0.1	0.1	0.2	0.4	0.4	0.2	0.2	0.1
41	0.2	0.3	0.2	0.4	0.4	0.6	0.3	0.1
42	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.1
43	0.3	0.1	0.1	0.4	0.3	0.4	0.3	0.1
44	0.2	0.1	0.1	0.3	0.3	0.3	0.2	0.1
45	0.3	0.3	0.7	0.7	0.3	0.5	0.5	0.2
46	0.6	0.7	0.6	0.6	0.8	0.8	0.7	0.1
47	0.4	0.6	0.2	0.4	0.4	0.5	0.4	0.2
48	0.1	0.2	0.2	0.1	0.3	0.8	0.3	0.3
49	0.6	0.7	0.6	0.7	0.6	0.8	0.7	0.1

Source: EPO-CESPRI database.

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