Sources, Appropriability, and Directions of Technological Change: The Cases of the United States and Italy *

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1. Introduction

In recent years the economics of technological change has developed new insights about the sources, forms and procedures of technological innovation. In particular, three basic elements of technological innovation have been identified: the knowledge base (*i.e.*, the scientific and technological base and the sources of innovation both internal and external to the industry), the various means of appropriation of the benefits from innovation and the directions of innovation pursued by firms.

The notion of the knowledge base conveys the idea that technological change in an industry is based on specific sets and combinations of basic and applied disciplines, such as physics, chemistry, operation research, or electrical engineering. The relevance and number of these disciplines affect the rate and direction of technical change in an industry in a complex and interactive way (Rosenberg, 1982; Nelson and Winter, 1982; Dosi 1988). In addition, techno-

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logical change may originate from various sources: internal to the firm (such as R&D), external to the firm but internal to the industry (such as other firms in the industry), and external to the industry (such as suppliers, users, and universities). All these sources of knowledge affect in different ways the rate and direction of technical change in different industries (Nelson and Winter, 1982; Kline and Rosenberg, 1986).

The concept of appropriability refers to the different means used by firms to protect their innovations and their proprietary knowledge from imitators in order to secure their stream of future profits. These means range from patents to secrecy, to lead times, to the continuous improvements of the initial innovations (Levin *et al.*, 1987).

Finally, as far as trajectories are concerned, Dosi (1982) suggested that in any given industry firms follow specific technological trajectories related to the different conditions of technological opportunity and appropriability, while Nelson and Winter (1982) introduced the concept of natural trajectories. The two notions are conceptually and empirically different. The notion of technological trajectories refers to a specific industry or to a single technology, such as transistors and integrated circuits in semiconductors or old pharmaceutical products based on chemistry and the new products based on biotechnology. The notion of natural trajectories refers to the directions of incremental improvements that may be common to more than one industry. Some of these trajectories are linked to process innovations, such as mechanization or changes in the scale of production, others are linked to product innovation, like the improvements in the performance of products (for an analysis of these issues see Malerba, 1992).

The basic hypothesis advanced in this paper is that in a specific industry there is a tangle between similar technological imperatives and means of appropriability valid across countries and country-specific factors related to different national systems of innovation which affect the sources of technological change and the direction of incremental technical change.

According to this distinction, we expect to find strong similarities across countries in the scientific and technological knowledge base underpinning the innovative process (*i.e.* knowledge and technological imperatives). More precisely, we expect that the scientific disciplines which are relevant to innovation decisions and procedures in a specific industry of a given country do not depend on the position of the country in terms of levels of scientific and technological capabilities. In fact, we expect that any specific technology is characterized by a specific knowledge base and by a specific paradigm that together define the opportunities and the constraints within which firms operate.

More complex and less clear are the mechanisms of the country effects and the national systems of innovation. We expect that the competence and innovative gaps between countries, the institutional and country factors linked to the specific features of a national system of innovation, the characteristics of demand facing the industry and the size of a country, play a role in affecting the sources of innovation and the innovative behavior of firms. Therefore, we expect these factors to determine differences across countries in the sources of technological change and trajectories of incremental technical change.

This paper examines the case of the United States and Italy. Following the Yale Survey of the American manufacturing industry (Levin *et al.*, 1987), a similar survey on opportunity and appropriability conditions has been carried out in Italy by the Confederation of Italian Industries (Confindustria, 1989). We used the results from the two surveys to construct a pooled data set. After controlling for the intercountry comparability of the data, we performed some exploratory tests about the differences between the two countries in the knowledge base, sources and directions of technological change, and means of appropriability.

The paper is organized as follows. Section 2 examines the differences in the main characteristics of the industrial structure of the two countries taking into account R&D intensity and international performance. Section 3 presents the basic features of the American and the Italian Surveys and the resulting data set. Section 4 discusses the results.

2. The United States and Italy: Two Different Countries

The existence of two similar surveys conducted in two different countries allows us to compare the patterns of innovation in two different environments. In this section we describe the two countries according to two main characteristics of the manufacturing industry:

the sectoral structure of production and the size distribution of firms, and the R&D expenditures.

The Italian and the American manufacturing industries show important structural differences. The United States is characterized by an industrial structure with a significant presence of large enterprises. On the other hand, Italian firms are much smaller and the average size of an Italian establishment is the smallest in Europe. Second, the composition of Italian industrial production has remained relatively stable in the past fifteen years. The relative importance of the traditional industries (*i.e.*, textile and clothing, footwear and furniture) did not decline as much as in the United States. In recent years, however, the Italian mechanical industries showed an unprecedented growth of production and a number of Italian firms became leaders in Europe in the production of machinery and equipment. Contrary to the United States, however, the relevance of high technology sectors in Italy is quite limited.

These two characteristics are consistent with the patterns of international competitiveness and R&D investment. Table 1 provides a picture of the different performance of Italy and the United States in a selected sample of industrial sectors over a range of five years. As expected, Italy performs better than the United States in traditional industries, while the United States is more competitive in high technology.

Table 1

EXPORT TO IMPORT RATIO: SELECTED INDUSTRIES

	Year	Italy	USA
Aerospace	1983	1.37	4.26
	1987	1.19	2.89
Electrical and electronic	1983	1.17	0.68
	1987	0.82	0.45
Office machinery and computer	1983	0.89	1.79
	1987	0.70	1.04
Pharmaceutical	1983	1.00	2.08
	1987	0.78	1.23
Other manufacturing	1983	1.41	0.65
	1987	1.22	0.47
Total manufacturing	1983	1.37	0.76
	1987	1.15	0.55
Technological balance of payments: coverage ratio	1983	0.25	7.30
	1987	0.38	6.65

Source: OECD, *Main Science and Technology Indicators, 1990-92.*

A more detailed look at the differences between the two countries is provided by the pattern of R&D spending of the last years. We consider some broad measures of innovative effort at the country level. Table 2 shows the pattern of Gross Expenditures on R&D in the two countries in the years from 1984 and 1990. The sources of financing and the sectors of execution are also considered. The figures regarding absolute expenditures are given in billions of current dollars adjusted for purchasing power parity for reasons of intercountry comparability.

Table 2

NATIONAL R&D: EXPENDITURE, FINANCING AND EXECUTION

	Year	Italy	USA
Billions current ppp $	1984	6.0	103.2
	1990	11.1	152.9
Percentage of GDP	1984	1.0	2.8
	1990	1.3	2.8
Industry financed %	1984	43.5	50.6
	1990	44.5	48.6
Government financed %	1984	52.9	47.7
	1990	50.6	49.3
Business enterprise executed %	1984	56.4	72.5
	1990	58.0	70.7
Higher education executed %	1984	18.8	12.8
	1990	17.7	15.7
Government executed %	1984	24.9	11.8
	1990	24.3	11.1

Source: OECD, *Main Science and Technology Indicators, 1990-92.*

Notice the difference in relative effort between the two countries. R&D expenditures as a percentage of GDP in the United States is almost twice as much as in Italy. Although Italy shows a small increase in the period, the gap is still wide and fairly stable. Table 2 shows a further difference between the two countries. While in the United States the financing of R&D expenditures is evenly divided between industry and Government, in Italy the share of the Government is much larger. Also in this case these differences are quite stable in time.

When considering the sectors of execution of R&D, an interesting difference between the two countries is highlighted. The average share of R&D executed by business enterprises in the United States is around 72% in the time period considered, while in Italy it is only around 57.5%. Furthermore almost 25% of R&D in Italy is performed by the Government. Considering that the Italian university system is almost completely managed by the Government, the share of R&D actually performed by Governmental Institutions is around 41% in Italy. This is an important point to make, given the differences in methods, procedures, incentives and objectives between private business and the public sector.

These differences are consistent with the patterns exhibited by the two countries in another indicator of R&D effort: Business Enterprise R&D. Table 3 provides information similar to Table 2 for private business R&D. The participation of the Government to the innovation process in industry is definitely stronger in the United States than in Italy.

TABLE 3

BUSINESS ENTERPRISE R&D: EXPENDITURE AND FINANCING

	Year	Italy	USA
Billions current ppp $	1984	3.4	74.8
	1990	6.4	108.2
Percentage of GDP	1984	0.6	2.0
	1990	0.8	2.0
Industry financed %	1984	75.9	68.7
	1990	75.5	67.0
Government financed %	1984	18.0	31.3
	1990	16.6	33.0

Source: OECD, *Main Science and Technology Indicators, 1990-92.*

The differences in the research efforts of the two countries are reflected in their technological performance. If we consider the Technological Balance of Payments (see Table 1) in the years 1983 and 1989, the Italian coverage ratio has been steadily lower than 1, while the American one has been higher than 5. Although the American position has been declining and the Italian one improving, the gap in technological performance is still fairly wide.

The picture emerging from this evidence is quite clear. The United States is a technological leader with a strong position in the production of high technology goods, Italy is a technological follower with a weak position in high technology products. Therefore, the comparative exercise proposed in this paper may highlight interesting similarities and differences in the innovation patterns in very different national environments.

3. The Yale Survey and the Confindustria Survey

In this section we briefly describe the characteristics of the two surveys used for our comparative exercise. We also provide a discussion of the major methodological issues implied by the qualitative nature of the data.

3.1 *The Yale Survey*

The Yale survey is an inquiry into the technological opportunity and the appropriability conditions in the American manufacturing industry. The data come from a survey of high level R&D executives and consist of informed opinions about the industry's technological and economic environment.

The questionnaire has been designed drawing upon the theoretical literature on technological change, the empirical literature on the economic impact of the patent system, and numerous case studies. The authors asked each respondent to report "typical experiences or central tendencies" within a particular industry. Respondents have been treated as "informed observers" of a line of business: this has encouraged co-operation, but produced heterogeneity in the responses within a single industry.

The questionnaire contains four parts. Parts 1 and 2 concern appropriability, parts 3 and 4 concern technological opportunity and technological advance. The parts on appropriability report on the effectiveness of the different means of protecting the competitive advantages of R&D, the limits of patents, the ways of acquiring the relevant information on a competitor's technology, the cost and time required to imitate the innovation of a rival. The parts on opportunity and technical advance refer to the links between sources of technological progress such as university-based scientific research and interindustry spillovers, and the pace and type of technological progress.

The sample consists of responses from 650 individual firms representing 130 lines of business. The sampling frame of the questionnaire is the lines of business defined by the Federal Trade Commission which in the manufacturing sector correspond to four digit SIC industries. The FTC lines of business are the most disaggregated level at which data on R&D are available.

3.2 *The Confindustria Survey*

Confindustria has conducted an inquiry into the quantitative and qualitative aspects of the patterns of technological change in the Italian manufacturing industry. A questionnaire has been mailed to 2500 firms. It required the respondent to be the director of the R&D department of the firm or, alternatively, the director of the Production and Engineering department.

The basic characteristics and scopes of the analysis are similar to the Yale survey. High-level executives from a representative sample of industrial firms have been asked to report their experiences within the industries and their responses have been treated as "informed opinions". A higher level of heterogeneity in the industry responses must be expected because the Confindustria questionnaire did not always ask to report "typical experiences or central tendencies" within the industry, but in some cases it asked to report firm-specific experience.

The questionnaire consists of five parts of which two are relevant to this paper. Parts 4 and 5 concern technological opportunity and appropriability conditions and the pace and type of technological advance. The sections on appropriability regard the effectiveness of different means of appropriation of the benefits from R&D, the limits of patents and the ways of acquiring information about competitors' technology. The sections on technological opportunity regard the importance of different types of interindustry spillovers and of university-based scientific research. The sections on technological advance regard the major directions of change pursued by firms and the speed of introduction of innovations.

377 firms have responded. 119 have declared that they do not spend in R&D although they do introduce technological innovations, while 258 have declared that they do spend in, and perform R&D. The 377 firms are framed into the NACE classification system and they cover 92 three- and four-digit NACE-industries.[1]

3.3 *Methodological Issues*

Answers to the various questions were given on a seven-point Likert scale, from not at all effective (1) to very effective (7). In both the surveys herein described there is substantial interindustry and intraindustry variation in the responses to the questionnaire. As Griliches (1987) noticed, this intraindustry heterogeneity in the survey data could be a source of substantial measurement error. There are three sources of heterogeneity that must be considered (see Levin *et al.*, 1987). First, the lines of business that form the sampling frame may be objectively heterogeneous as to the products and technologies that they include. Second, the respondents' perception of the tendencies within the industry may be affected by the firms' specific policies and strategies. Third, there is an inherently subjective effect in the use of semantic scales like the seven-point Likert scale used in the two surveys.

All these three sources of intraindustry heterogeneity become more important in the case of a comparison between two countries. In fact, Levin *et al.* (1987) stress that the first two sources of heterogeneity may be overlooked, while Griliches (1987) points out that the third may induce errors in the observations. One way out of this problem is to consider the data as interval data. We are, however, interested in making comparisons between questions in order to shed light on the differences and similarities between Italy and the United States in their patterns of technological progress. Therefore, the data must be considered ordinal. Some further caution is needed in this respect. First, the data of the two surveys may not accurately rep-

[1] The reason for such a low response ratio is related to some of the structural characteristics of the Italian industry: the size of firms performing R&D can be very small in Italy and active firms are difficult to identify; for this reasons the questionnaire was sent to many firms that actually might have not been active in research and did not bother to answer back.

resent the true evaluations of the respondents. Second, they may not grasp potential non-linearities between response categories. However, solutions to these problems are not simple.

3.4 *Sampling Procedure*

In constructing our sample various problems have had to be solved. Apart from the methodological difficulty arising from the survey method, the issue of direct comparability of the two country samples must be addressed.

First, firms in the two surveys have been classified following two different systems. The Yale survey is based on the SIC code, while the Confindustria survey is based on the NACE system. It has been possible to identify 38 manufacturing sectors for which the matching between the SIC and the NACE codes is complete. The number may appear small compared to the original ones (130 lines of business for the Yale survey and 92 sectors for the Confindustria survey), but the reduction is due to two reasonable constraints that we imposed on our sample. First, we considered only the observations corresponding to R&D performing firms. Second, we decided to exclude from the sample those lines of business and sectors which contained less than 2 observations. The aim has been to make the two samples consistent in terms of respondents per line of business.[2]

A second problem has been the comparability of the lists of items included in the questions proposed in the two questionnaires. It has been possible to select the following four sets of dimensions of innovation:

i. basic and applied scientific fields;
ii. sources of technological change;
iii. directions of technological change;
iv. means of appropriability;
v. limitations of patents as means of appropriability.

Table 4 provides the list of items included in the five sets.

[2] The correspondence Table, not reported here, is available on request from the authors.

TABLE 4

ITEMS INCLUDED IN THE SURVEY

Basic and applied scientific fields	
Biology	biology and natural sciences
Chemistry	organic and inorganic chemistry
Mathematics	mathematics
Physics	physics
Agricultural science	agricultural science
Operation research	operation research
Computer science	computer science
Material science	material science
Metallurgy	metallurgy
Medical science	medical science
Chemical engineering	chemical engineering
Mechanical engineering	mechanical engineering
Electrical engineering	electrical and electronic engineering
Sources of technological change	
Firms	firms within the sector
Material suppliers	material suppliers
Manufacturing equipment	manufacturing equipment suppliers
R&D equipment	R&D equipment suppliers
Users	final users of the product
University	university based research
Independent	independent inventors
R&D presence	presence of an R&D department within the firm
Directions of technological change	
Scale	change the scale of the production process
Mechanization	mechanization and automation of operations
Input materials	increase the quality of input materials
Physical properties	improve the physical properties of the product
Performance	improve the functional performance of the product
Dominant design	shift to a dominant product design
Segmentation	specialize in specific market segments
Customization	tailor the product to the users' needs
Means of appropriability	
Patent	patent the innovation to prevent imitation
Secrecy	keep secret the knowledge embodied in the innovation
Lead times	lead times in the introduction of the innovation
Limitations of patents as means of appropriability	
Patent delay	difficult to patent new products and processes
Validity	difficult to prove the validity of the patent
Enforce	difficult to enforce the patent against violations
Around	easy to invent around the patent
Information	disclose too much information about the innovation

4. The Patterns of Technological Change in the United States and Italy: Comparative Results

This section presents and discusses the results of the comparative exercise.[3] Some explanations and conjectures are advanced, although we defer to the final section a general appraisal of the evidence obtained from our exploration. For simplicity of exposition we do not report the details of the statistical analysis we performed, although, the correlation analysis and the t-tests are available on request.

4.1 *Basic and Applied Scientific Fields*

The knowledge base in terms of basic and applied scientific fields seems to be the same in the American and Italian industries. R&D managers were asked to rate different academic subject with respect to their importance for industrial innovation. As Table 5 shows, the ratings of the various disciplines is quite similar in the two countries: computer and material sciences were considered the most important subjects for industrial innovation, while agricultural and medical sciences the least important. The t-statistics do not highlight major differences across countries, with the exception of operation research (higher in the United States) and material sciences and electrical and electronic engineering (higher in Italy).

Spearman rank correlation analysis confirms a similar ranking for 8 out of 15 fields of science. The fields which are non correlated are material sciences, medical sciences, chemical engineering and mechanical engineering. Metallurgy shows a significant negative Spearman correlation coefficient.

[3] The results of the two surveys have been aggregated using country specific aggregation weights based on the contribution of each industry to the gross domestic product originating in the manufacturing sector. The comparative results are quite invariant with respect to the choice of the aggregation weights and they do not change when using a common aggregator for the two countries.

Table 5

BASIC AND APPLIED SCIENTIFIC FIELDS

	Italy			USA		
	Obs.	Mean	Std. Dv.	Obs.	Mean	Std. Dv.
Biology	36	1.74	1.16	38	1.95	1.23
Chemistry	38	3.59	1.73	38	3.26	1.11
Mathematics	37	2.74	1.05	38	2.80	0.87
Physics	38	3.76	1.40	38	3.16	1.03
Agricultural science	36	1.72	1.14	38	1.82	1.30
Operation research	37	3.09	1.19	38	3.26	0.93
Computer science	38	4.88	1.01	38	4.27	0.77
Material science	38	4.95	1.21	38	4.15	0.88
Metallurgy	38	3.96	1.72	38	3.46	1.09
Medical science	36	1.87	1.51	38	1.94	1.22
Chemical engineering	38	3.70	1.45	38	3.20	0.90
Mechanical engineering	38	4.49	1.62	38	3.84	1.13
Electrical engineering	37	5.09	1.29	38	3.59	1.28

4.2 *Sources of Technological Change*

Only few of the sources of technological change have the same relevance in the United States and in Italy. R&D managers were asked to rate the relevance of various intersectoral sources of technological change in an industry. As Table 6 shows, only manufacturing equipment suppliers and R&D equipment suppliers have the same importance (in terms of absolute value) in affecting technological change in an industry. These two channels, however, have a different ranking position in the two countries, as Spearman rank correlation shows.

Table 6

SOURCES OF TECHNOLOGICAL CHANGE

	Italy			USA		
	Obs.	Mean	Std. Dv.	Obs.	Mean	Std. Dv.
Firms	38	4.64	1.05	38	5.95	0.54
Material suppliers	38	3.53	1.30	38	4.58	1.00
Manufacturing equipment	38	4.65	0.93	38	4.79	0.78
R&D equipment	38	4.12	1.02	38	3.95	0.90
Users	38	5.05	0.93	38	4.17	0.78
University	38	2.67	0.74	38	3.23	0.79
Independent	38	2.04	0.95	38	3.06	0.91
R&D presence	38	4.48	0.76	38	4.83	0.69

In the United States firms within an industry have the most important role in fostering innovation, while in Italy final users are the most important element of change. A possible explanation is that American firms operate at the frontier of technology in an environment that is quite conducive to innovation. On the other hand, Italian firms are more of a follower type and operate inside the current technological domain. This situation induces Italian firms to focus on customers, trying to interact more closely with the specific users in order to carve out specific market niches. In addition, note that material suppliers play a more important role in the United States than in Italy. This is consistent with the above explanation because advanced materials are a major element in most high technology products, contributing highly to improve their characteristics and performance.

A very important result concerns the role of universities. Both countries rate university as the least important source of technological change (after independent inventors), but Italian firms rate the contribution of the university much lower than their American counterparts (the t-statistics concerning the difference in the two values is significant). This is probably due to institutional factors: in Italy the university system is more separated from industry and the research network less advanced in science and technology than in the United States.

4.3 *Directions of Technological Change*

When we consider the directions of technological change, similarities between the Unites States and Italy emerge in a few cases. As Table 7 shows, American and Italian firms rated similarly the improvements in the performance of products (considered the most important direction of change), the mechanization of production processes, the improvements in input materials, the tailoring of products to individual customer needs, and the improvements of the physical properties of products. The first four directions of change have also a significant Spearman rank correlation coefficient.

TABLE 7

DIRECTIONS OF TECHNOLOGICAL CHANGE

	Italy			USA		
	Obs.	Mean	Std. Dv.	Obs.	Mean	Std. Dv.
Scale	38	3.45	1.07	38	4.45	0.93
Mechanization	38	5.10	1.19	38	4.89	1.04
Input materials	38	4.52	0.90	38	4.65	0.68
Physical properties	38	4.87	1.00	38	4.90	0.99
Performance	38	5.31	0.98	38	5.72	0.77
Dominant design	38	4.38	1.00	38	3.98	0.76
Segmentation	38	4.55	0.95	38	5.21	0.75
Customization	38	4.81	1.31	38	4.43	1.11

The other directions of change received different scores and different rankings by American and Italian firms. The differences in the values and rankings assigned to the change in the scale of the production process and to the segmentation of products (higher in the United States) and to the movement toward a dominant design (higher in Italy), may be explained by institutional and country-specific factors. In particular, the greater role assigned in the United States to the change in the scale of the production process may be related to the scale of the American market compared to the Italian one. Similarly, the segmentation of products shows greater scores in the United States than in Italy probably because this strategy is more feasible in a larger market.

4.4 *Means of Appropriability*

American and Italian industries appear to be quite similar with respect to the perceived effectiveness of the alternative means of appropriating the benefits from innovation. As a general result, the patterns of appropriability seem to be independent of the specific technological level of the country.

As Table 8 shows, in both countries lead times are considered the most important channel for appropriating the results from R&D. Secrecy, though less effective than lead times, especially in the United States, is considered more important than patents in protecting innovations. This confirms the results of a survey on the means of appropriability in Italy carried out in 1988 and based on a sample of Italian firms patenting in the United States (Malerba and Orsenigo, 1990). The Malerba-Orsenigo survey found a great similarity between the Italian and the American cases in terms of relevance of the means of appropriability of innovative firms.

TABLE 8

MEANS OF APPROPRIABILITY

	Italy			USA		
	Obs.	Mean	Std. Dv.	Obs.	Mean	Std. Dv.
Patent	38	3.91	1.44	38	3.90	0.90
Secrecy	38	4.06	1.24	37	3.78	1.50
Lead Times	38	5.39	1.02	38	5.29	0.67

4.5 *Limitations of Patents as Means of Appropriability*

The last set of issues regards the various ways competitors could circumvent and limit the effectiveness of patents as an instrument for guaranteeing appropriability. As Table 9 shows, in both countries the values assigned to the various limitations are quite similar and close to each other. The difficulty to prove the validity of a patent, the disclosure of too much information and the difficulty to enforce the patent against violation, are all considered of medium importance both in the United States and in Italy.

TABLE 9

LIMITATIONS OF PATENTS AS MEANS OF APPROPRIABILITY

	Italy			USA		
	Obs.	Mean	Std. Dv.	Obs.	Mean	Std. Dv.
Patent Delay	36	4.29	1.18	38	4.05	0.92
Validity	36	3.84	1.06	38	3.94	0.96
Enforce	36	3.95	0.89	38	4.16	0.80
Around	36	2.98	0.92	38	5.45	0.66
Information	36	3.88	0.97	38	3.88	0.86

The only major difference between the American and Italian cases concerns the relevance of the ease of inventing around patents. In Italy this limitation ranks close to the lowest, in terms of importance, while in the United States it ranks the highest. This difference is probably related to the fact that American firms are surrounded by a more competitive environment at the technological frontier, while in Italy, where competition for the most innovative products is probably more relaxed, patents are more effective in constraining imitation by competitors.

5. Final Remarks

The comparison between the Italian and the American cases with respect to the scientific and technological knowledge base underpinning innovative activities, the sources of technological advance, the directions of innovation, the means of appropriability and the limitations of patents as means of appropriability, highlights the following features of the patterns of innovation.

Strong similarities both in terms of values and in terms of rankings emerge for the scientific and technological knowledge base underpinning innovative activities across the two countries. This supports the idea that similar knowledge and technological imperatives (in terms of basic and applied scientific fields) are faced by firms of different countries aiming to be innovative in a specific industry.

With few exceptions, similarities seem also to exist in the relevance of various means of appropriability and in the limitations of patents as means of appropriability.

On the contrary, differences exist in most of the sources of technological advance and in some of the directions of incremental innovation as a consequence of institutional and country-specific factors.

Such features of technological innovation seem to imply similarities across countries in the scientific dimensions of technological opportunity and in the major means of appropriability and differences across countries in the sources and overall organization of the innovative process (in terms of major external actors involved and channels through which technological change is introduced in an industry) and in the specific directions of incremental technical change.

Our results cannot be pushed too far in drawing strong conclusions about differences and similarities of sources, appropriability and directions of technological innovation across countries. The data gathered in the Yale and Confindustria surveys have only allowed us to carry out for the first time an exploration of the qualitative characteristics of the innovation patterns in two different countries. The evidence provided by our comparative exercise however is broadly consistent with evidence from more conventional sources and industry studies.

Much more work is needed to set on a firmer ground some of the conjectures advanced in order to explain some of our empirical results. A better understanding of the process of technological change cannot be achieved without disentangling the puzzles that such conjectures address about similarities and differences in some of the key dimensions of technological innovation across countries. We consider the comparative exercise presented in this paper as a first step in that direction.

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