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Technological growth in the Italian economy: some indicators compared

Andrea Raggi
Istituto di Merceologia, Faculty of Economics, University of Bologna, Piazza Scaravilli 2, I-40126 Bologna, Italy

Abstract

The determination of the effects caused in a productive system by the introduction of new technologies requires a previous objective measurement of technological innovation. With this aim, several technological indicators have been proposed in the literature; in this paper, such indicators are reviewed and the main limitations of each are pointed out. Moreover, in order to obtain more information on their reliability, some indicators (patents, R&D expenditures and technological balance of payments) were tested by applying them to the measurement of innovation growth for 20 product groups of the Italian economy. For most examined product groups the technological growth rates resulting from different indicators did not agree and in some cases were totally discordant. This leads to the conclusion that the use of a single indicator does not seem to be acceptable and no statement should be made on innovation growth levels unless different indicators give the same concordant results.

1. Introduction

The entry of new technologies in a productive system causes various effects either at the microeconomic or at the macroeconomic level. These effects are often hard to quantify and studies are needed in order to improve their objective determination. The first problem to be faced when correlating technological innovation with the effects it produces is the objective measurement of innovation itself. Various technological indicators have been proposed in the literature with the aim of giving a measure of technological innovation. The aim of the research work reported on in this paper is to compare these indicators in order to obtain information on their reliability.

2. Technological indicators

Even though technological innovation has to be considered a single process, the technological indicators proposed in the literature are divided into input indicators and output and impact indicators [1].

Input indicators measure the factors involved in producing technological innovations and mainly concern the amount of human and financial resources devoted to research and development activities; R&D expenditures are the most important indicator of this kind.

Output and impact indicators are intended to give a measure of innovation through the effects and the results which it produces. Output and impact indicators can be classified into:

- statistics on patents;
- technological balance of payments;
- statistics on innovations (direct surveys);
- trading in high-tech products;
- indicators of scientific output;
- other lesser indicators.

Only two among the proposed indicators (statistics on R&D expenditures and direct surveys on innovations) were specifically created for the measurement of technological innovation; the others were adopted from other application fields. Here follows, for each indicator, a brief description and a few considerations on their structure, data availability and main limitations.

2.1. Research and development expenditures

Research and development can be defined as all systematic activities aimed at increasing the amount of scientific knowledge and converting it into useful applications. R&D is the first phase of the innovation process, but not all R&D activities produce innovations. It is obvious, indeed, that not all research activities result in new knowledge and that scientific knowledge cannot always be developed into innovations. Therefore, R&D is an innovation input whose results cannot be fully anticipated. As a technological indicator, it includes human and financial resources devoted to scientific research by private and public institutions.

First attempts to collect R&D statistics date back to the 1930s in the USSR and the 1940s in the USA [2]. However, a systematic gathering of statistical data on R&D in the United States was started by the National Science Foundation (NSF) in the 1950s. Data on R&D in their member countries are also collected by UNESCO [3], the OECD — which has been publishing biennial surveys since 1963 [4] — and the EEC [5, 6]. In Italy, ISTAT (Italian National Statistical Bureau) periodically issues R&D statistics where R&D is classified according to firms' economic activity and product groups [7]. Statistics on R&D have become widespread in many countries and, to make them internationally comparable, UNESCO has published some recommendations on data collection and classification [8].

Statistics on R&D expenditures present some limitations as a technological indicator. First of all, as stated above, R&D does not necessarily yield innovation. On the other hand, activities other than formal research (e.g. learning by doing) may be determinant in producing incremental innovation [9]. Therefore, R&D expenditures are not the only innovation source[1].

Moreover, R&D may assume a different importance according to the industrial sector and the firm size. Some sectors (e.g., electronic, pharmaceutical and chemical) present a more formal and more easily quantifiable research activity than others [10]. Large firms have a higher R&D intensity than smaller ones, as the former usually formalize their innovation activity as laboratory research, while the latter do not [11, 12]. Thus, sectors with a high firm concentration level may have higher R&D expenditures than the others.

Other limitations are connected with the structure of R&D statistics. For instance, R&D expenditures are classified according to the main activity of the firm which met them. This could be misleading in the case of diversified enterprises. It has been shown that in the USA only 36% of R&D expenditures in the metal products sector, for instance, are addressed to products of the same sector [13]. Moreover, from R&D statistics we may obtain information on the sectors where innovation activity originates, but not on those where it is utilized.

2.2. Patents

Patents are documents issued by governments and/or international offices to establish a protection on inventions, which may be exploited only with the patentee's permission. Data on patents are usually collected for administrative uses and not with the aim of analysing technological innovation. Nevertheless, patent statistics are considered by most authors an interesting and sufficiently reliable technological indicator. These statistics are made available by patent offices, some international organizations and information processing firms. Centres gathering national and international databases on patents exist in many OECD countries (e.g., the US Office for Technology Assessment and Forecast).

Among the international organizations, the World Intellectual Property Organization (WIPO) has been publishing, since the end of the 1970s, regular statistics on applications for patents and obtained patents for a number of countries. Moreover, the International Patent Documentation Centre (INPADOC), headquartered in Vienna, has developed a database containing about 10 million patents from 50 countries, with the possibility of selecting patents concerning the same invention, thus creating patent families. Additional information on patenting activity in the European countries may be obtained from the European Patent Office, which, since 1978, has been granting patents extending their validity to all member countries of the agreement.

As for Italy, the only official patent data collector is the Central Patent Office (Ufficio Centrale Brevetti). These data are, however, not systematically collected; this, together with a not entirely suitable classification and the incompleteness of patent collection, make these data difficult to use. Moreover, under Italian law, patents may be obtained after the simple ascertainment that the applications fulfil legal requirements, without any in-depth assessment of the technological and scientific novelty of the invention. Most applications, indeed, are accepted and very few amendments to applications are required by the Central Patent Office [14]. These limitations have led some researchers to use data sources other than Central Patent Office [15].

Despite their widespread use, patent statistics present some limitations which do not allow them, in our opinion, to be a fully reliable indicator of technological innovation. Some of these limitations are even recognized by authors using patents as a technological indicator. The first limitation is that not all inventions are patented, and not all patented inventions develop into innovations, especially when the patentee is a private individual and not a firm[2]. Secondly, even if a patented new process or product is adopted as an innovation, a certain time lag occurs, which does not show up in patent statistics. This phenomenon is referred to as 'sleeping patents'. Finally, the patenting trend is not the same for all industrial sectors and invention types. Where imitation is more likely, patenting intensity is higher, but it does not necessarily correspond to a higher innovation rate.

2.3. Technological balance of payments

International technology transfer may take place in different ways, such as direct investment abroad, transfer of 'disembodied' technology (patents, licences, know-how, etc.) and sale of technology-incorporating goods [16].

The technological balance of payments (TBP) measures the financial flows deriving from transactions of industrial and intellectual property rights, such as patents, licences, technical assistance and know-how. TBPs of different countries may also include a wider range of transactions [17]. Therefore, in order to achieve a better international comparability, the present trend is to consider only the above-listed transactions, which best represent technology transfers [18, 19].

Italian TBP data have been collected since 1956, although they have assumed a more detailed form only since 1972; further refinements were introduced in 1979. They include currency transactions related to the following operations: patents, licences, trade marks, designs, inventions, related technical assistance and know-how [20]. In Italy, TBP data are collected by the Italian Exchange Office (UIC). Since 1979 these data have no longer been published, but, after being processed, they are made available by the UIC through the National Research Council (CNR).

TBP statistics are collected by several countries, now, through financial and administrative currency controls related to international transactions. In some countries, direct surveys of industrial firms are taken in order to obtain more reliable and meaningful results. Data collected in the different countries are then processed by international organizations (e.g. OECD), thus making international comparisons possible.

TBPs, as well as R&D expenditures and patents, present some limitations as a technological indicator. First of all, as the TBP is only concerned with transferred technology, it does not take into consideration all those technological innovations which are the object of no commercial transactions or which are exchanged without any financial transactions (as in the case of patent swap or cross-licensing agreements). Secondly, since only international technology transfers are recorded, innovations which are transferred within a country are excluded. Moreover, multinational corporations may greatly affect TBP transactions while operating their global cost or profit strategies. TBP transactions, indeed, are strongly concentrated in a small number of firms. It should also be pointed out that TBP payments and receipts are seldom recorded at the very time when technology transfers take place; when technology is transferred, the counter value may be only partially paid at once and, then, be settled later, normally by several payments (e.g. royalties). Thus, a TBP's financial transactions recorded in a certain year may refer to technology transfers previously incurred [17]. Moreover, technology transfers, when they are directed towards newly industrializing countries rather than developed countries, may not refer to innovative technologies but to mature ones.

Finally, some considerations about the international comparability of TBPs. The transactions included in the technological balances of payments of the various countries are not the same; besides technology transfers in the strict sense of the term, technical services (consultancy, transfer of experts, market surveys, personnel training and teaching) or transactions not directly related to technology (trade marks, management services) may also be involved. Moreover, international comparability may be limited by the different survey procedures and by the way data are processed and published [17].

2.4. Direct surveys

Instead of trying to measure innovation through technological indicators, it might, obviously, be possible to quantify it through direct surveys. Unfortunately, the complexity of technological innovation and the difficulty in defining it exactly make this kind of operation difficult to realize. Methodologically, there does not yet exist an accepted procedure for carrying out such surveys; however, some studies have been made which may form the basis for further developments.

In Italy, ISTAT, with the collaboration of the Institute for Studies on Scientific Research and Documentation of the Italian National Research Council (CNR), conducted, during the period April 1987–April 1988, a survey on technological innovation in the Italian manufacturing industry [21]. The managers of about 35 000 firms were asked to complete a questionnaire containing items on innovations adopted during the previous five years and innovation programmes for the following five years. About 71% of the questionnaires were returned completed. Other surveys on innovation were conducted in France [22], Germany [23], the UK [24] and the USA [25].

It should be noted that the ISTAT–CNR survey gives information on innovation diffusion, rather than mere innovation generation, without even providing any specification on the technological and economic importance of the innovation itself. The identification of the innovations, made by the operators asked to complete the questionnaires, is an arbitrary element of the survey; in addition, the possibility of misunderstanding and mistakes represents a further error source. However, as already pointed out, innovation is a complex phenomenon, not easy to identify and quantify separately.

2.5. Trading in high-tech products

Data on trading in high-tech products represent a quite recently proposed technological indicator, which consequently is still being defined. The use of this indicator requires the definition and identification of high-tech products.

The more traditional method (top-down) consists of ranging productive sectors, by using appropriate indices, into three technological intensity groups (low, medium, high) [26]. All products belonging to high technological intensity sectors are then considered high-tech products. The main problem is the choice of the appropriate ranging index; some authors have proposed the R&D expenditures/value added and the R&D expenditures/sales ratio [27, 28]. A limitation of this method is that it disregards the technological heterogeneity existing within a single sector. Indeed, some products belonging to a technology-intensive sector may not be high-tech. Another method (bottom-up) consists of making, within the technology-intensive sectors, a sort of product technological screening, thus excluding low technology productions [29].

In recent work carried out by the Italian National Institute of Foreign Trade (ICE), attention was focused on the products of high R&D intensity firms. The reason for such a choice is that, unlike other technology-intensive firms, these can be considered the main innovation generating sources for the whole industrial system [30]. However, despite several studies carried out on this subject, there still remain a number of unsolved problems, particularly concerning the product classification procedures. Besides the above-stated difficulty in identifying the appropriate ranging index, there is the subjectivity of fixing index threshold values for low, medium and high technological intensity groups. Moreover, such classifications do not generally take into account the indirect technology contents of products, that is technology embodied in the production factors employed.

2.6. Scientific output indicators

To complete this survey, a few notes on scientific output indicators are necessary. Unlike the other output indicators examined, which are concerned with the results of scientific/technological activities (mainly performed in industry), these indicators are intended to measure the output of fundamental research, which is prevalently carried out by academics.

The most well-known and widely used among these indicators are bibliometric indicators (scientific publications and citations) and 'peer reviews'. The former are based on the number of publications, citations and co-citations referred to in scientific works; the latter consists of the evaluation of scientific works by other scientists and researchers.

While these indicators may be useful for the assessment of the state and perspectives of science in a country or a scientific branch or institution, even though some limitations have been highlighted, they can hardly be suitable for measuring technological innovation.

2.7. Other lesser indicators

Finally, there are a number of minor indicators which can only marginally express the state of science and technology of a certain productive sector or country. Their use is infrequent because of their poor suitability for giving a measure of technological innovation.

The most common ones are:

- productivity indices, which are used on the postulate that technological innovation improves productivity;
- capital investments, based on the assumption that new machinery and equipment often embody technical advances;
- industrial performance indices, which are proposed assuming that innovation improves the competitiveness of firms.

3. Study results

As has been seen, several indicators have been proposed to measure technological innovation and, even though a few of them have been used in a variety of applications, each presents some limitations — often acknowledged by their proposers themselves — which may raise doubts on their full reliability. In order to analyse their behaviour, several indicators were tested by the author by applying them to the measurement of innovation growth for 20 product groups of the Italian economy. The indicators employed were an input indicator (R&D expenditures) and two output indicators (patents and technological balance of payments), which are generally considered the most mature and reliable ones.

3.1. Description of data

Some problems have been encountered in finding data and processing them and, when changing from the theoretical formulation to the actual application, some simplifications have been introduced without, however, compromising the validity of the model.

Here follows a description of the data sources used for our analysis.

3.1.1. Patents

As has already been stated, the only official source for patent statistics in Italy is the Central Patent Office, whose data, for a number of reasons already mentioned, are not readily and easily usable. Thus we decided, following the example of other researchers, to use the data on Italian firms' patents obtained in the USA [31]. Indeed, an analysis conducted on a sample of more than 500 patents has demonstrated that Italian inventions patented abroad are a better technological innovation indicator than domestic patents [32].

The reasons why we chose the Italian patents obtained in the USA are various. The first reason is that the USA is the foreign country where Italian patents are extended most widely. From the above-mentioned analysis [32], it was shown that an extension application was presented for 44·2% of the Italian patents towards the USA, 22·1% towards Germany, 21·6% towards France, 20·8% towards Japan and 16·5% towards the UK (Table 1).

3.1.2. R&D expenditures

The data on R&D expenditures that we used are those published by ISTAT [7].

TABLE 1. Italian patenting abroad

Country	Patent applications		
	1977	1981	1984
USA	1224	1384	1636
Germany	1106	579	548
Japan	478	583	702
France	105	838	630
UK	855	646	526

3.1.3. Technological balance of payments

Data on international technology transactions are collected, in Italy, by the UIC. The data we used were obtained directly by the UIC in Rome.

Since we wanted to compare the technological innovation growth rate for various product groups by using different indicators, the first problem we had to face was to make the product classifications of the three indicators comparable. The data on patents follow the US Standard Industrial Classification (SIC). In order to make this classification comparable with the other two, we had to eliminate or unite some product groups, thus reducing the number to 20. In this process we had to make a few assumptions and simplifications while trying to minimize subjective points.

Classifications used for TBP and R&D statistics are actually the same, even though in the latter case product group denominations are more concise; indeed, they both follow customs duty product classification. To make them comparable to the SIC, they, too, were reclassified into 20 groups. Table 2 lists the product groups of the SIC, while those of the TBP and R&D classifications are listed in Table 3, using the wider denominations. Finally, Table 4 contains the denominations of product classes used for our analysis, and their correspondence to the above-mentioned classifications.

3.2. Growth rate calculation

In order to measure the technological innovation change, the percentage growth rates (I) of the different indicators were calculated with reference

TABLE 2. Standard Industrial Classification (SIC)

Code	Description
1	Food and kindred products
2	Textile mill products
3	Chemical and allied products
4	Chemicals (excl. Drug & med.)
5	Ind. inorganic and organic chemicals
6	Industrial inorganic chemicals
7	Industrial organic chemicals
8	Plastic materials & synth. resins
9	Agricultural chemicals
10	All other chemicals
11	Soaps, detergents, cosmetics
12	Paints, allied chemicals
13	Miscellaneous chemical products
14	Drugs and medicines
15	Petroleum/Nat. gas extraction/Ref.
16	Rubber and miscellaneous plastic products
17	Stone, clay, glass, concrete prods.
18	Primary metals
19	Primary ferrous products
20	Primary & secondary non-ferrous products
21	Fabricated metal products
22	Machinery (excl. Electrical)
23	Engines and turbines
24	Farm & garden mach. & equip.
25	Construction, mining, matl. hdlg. mach.
26	Metal working mach. & equip.
27	Office computing, acctg. mach.
28	Other machinery (excl. Electrical)
29	Spec. ind. mach. (excl. Metal wrk)
30	General ind. mach. & equip.
31	Refrigeration, service ind. mach.
32	Misc. machinery (excl. Elec.)
33	Elec., electrnc. mach., equip., suppl.
34	Elec. equip. (excl. Communication equip.)
35	Elec. transmission & distr. equip.
36	Elec. industrial apparatus
37	Other elec. mach., equip., suppl.
38	Household appliances
39	Elec. lighting & wiring equip.
40	Misc. elec. mach., equip. & suppl.
41	Comm. equip. & electrnc. components
42	Radio, TV receiv. (excl. Comm. types)
43	Electrnc. comp. & access & comm. equip.
44	Transportation equipment
45	Motor vehic. & oth. trans. eq. (excl. Air)
46	Motor vehicles & MV equip.
47	Guid. missiles & space vehicles, parts
48	Other transportation equipment
49	Ship, boat building & repairing
50	Railroad equipment
51	Motorcycles, bicycles & parts
52	Misc. transportation equip.
53	Ordnance (excl. missiles)
54	Aircraft & parts
55	Professional & scientific instruments
56	Unclassified patent
59	All other industries

to a certain time lapse (t_1, t_2), following the formula

$$I = [(b - a)/|a|] \cdot 100$$

where a and b are the values of the indicator, respectively, at times t_1 and t_2.

On the basis of data availability, t_1 and t_2 were chosen to be the years 1981 and 1987 in the case of patents and TBP. As to R&D, the chosen years were 1980 and 1986 in order to take into account the time lag that usually elapses between R&D expenditure and invention. Indeed, in the literature [33], a one-year time lag was found between R&D expenditures and Italian patents in the USA. However, it must be remembered that the assumed time lag is an average value; the actual time lags may differ according to the various sectors and R&D activities.

In the growth rate calculation a deflating process was needed when monetary values were involved. The first problem we had to face was the choice of the most suitable price index numbers. As the theoretically most suitable index numbers were not available from ISTAT, we chose the best fitting ones from among the available indices (Table 5). In order to make the base period of the available index numbers uniform, we used an approximate method consisting of dividing all index numbers for the various years corresponding to the old base period by the index number corresponding to the new base period and expressing the results as percentages [35].

3.3. Presentation of the results

Table 6 shows the percentage growth rates of the indicators considered for the 20 product groups[3]. In order to make their comparison easier, the rates have been arranged, for each indicator, in decreasing order and listed in Table 7. At a first general look, it appears evident that in most cases the considered indicators gave different results. It can be easily seen that, for more than 50% of the product groups, the different indicators even recorded growth rates of the opposite tendency; this means that, in the time interval examined, the same product group

TABLE 3. TBP classification

Code	Description
60.00	*Livestock, vegetable and animal products*
62.00	*Food, drink and tobacco*
62.01	Preserved food products
62.10	Other food products
64.00	*Minerals and ores*
64.01	Metallic and non-metallic ores and minerals
64.05	Radioactive ores
64.10	Fossil coal and peat
64.15	Liquid and gaseous petroleum derivatives
64.30	Bituminous materials
64.35	Electric power
66.00	*Chemicals*
66.01	Inorganic chemicals
66.05	Primary organic compounds and their derivatives
66.10	Basic pharmaceutical chemicals and other organic chemicals
66.15	Drugs
66.20	Natural, mineral and chemical fertilizers
66.25	Dyeing and tanning extracts; dyes; paints; inks
66.30	Essential oils and resinoids; perfumery; cosmetics
66.35	Soaps; organic detergents
66.40	Photosensitive materials
66.45	Plant protection products
66.50	Other chemicals
68.00	*Rubber and plastics*
68.01	Artificial and synthetic plastics
68.05	Natural and synthetic rubber
70.00	*Leather and furs*
70.01	Leather
70.05	Leather goods; furs
72.00	*Timber, charcoal, cork*
74.00	*Materials for paper mills*
74.01	Paper and paper-converting
74.05	Bookmaking
76.00	*Textiles*
76.01	Natural textile fibres
76.10	Artificial and synthetic textile fibres
76.20	Textile products
78.00	*Footwear, hats*
80.00	*Stones, chalk and concrete working; ceramics*
82.00	*Pearls, gems, precious metals*
84.00	*Non-precious metals*
84.01	Ferrous metal products
84.10	Non-ferrous metal products
84.20	Tools
86.00	*Equipment and machinery; electric materials*
86.01	Internal-combustion and piston engines
86.05	Other engines, hydraulic and steam turbines
86.10	Miscellaneous industrial equipment and machinery
86.20	Machine tools
86.25	Typing and calculating machines; office equipment
86.30	Automatic data processing machines; magnetic and optical input devices
86.35	Nuclear reactors
86.40	Other machinery and equipment
86.45	Power production and transformation apparatus
86.50	Built-in motor household appliances
86.55	Radio and TV equipment
86.60	Electronic tubes and components, semiconductors, electronic microstructures
86.65	Wires
88.00	*Transport equipment*
88.01	Railroad equipment and parts
88.10	Road transport equipment
88.20	Aircraft and space vehicles
88.30	Water navigation vessels and equipment
90.00	*Optical and medical-surgical instruments; image and sound equipment*
90.01	Medical and surgical instruments, X-ray instruments
90.10	Precision and control instruments; watches and clocks
90.20	Image and sound recording and reproduction equipment (incl. supports); musical instruments
92.00	*Weapons and ammunition*

experienced technological growth according to one of the selected indicators, or technological decline according to another.

With the sole aim of rapidly and synthetically comparing the indicators' behaviour, the 20 product groups were divided into classes of different growth rates (high, medium, static and decreasing) according to each indicator (Table 8), although we were aware of the arbitrariness of this classifying process. The assignment of the product groups to one of the four growth rate classes was made in accordance with the criteria shown in Table 9. As to patents, the classifying ranges were chosen on the basis of those commonly used in the USA for reporting world patent growth rates. As to R&D expenditures, the ranges were obtained by doubling the limits set for patents; this decision was taken because of the higher R&D expenditure growth rates, in comparison to other industrialized countries, that the Italian economy experienced in recent years. TBP was assimilated to patents.

Only three product groups (Aircraft and space vehicles; Paints and allied chemicals; Rubber and plastics) were equally classified in accordance with all three technological indicators, while seven product groups obtained a different classification for each indicator. Even if the chosen ranges were modified, the results would probably not be very different.

TABLE 4. Product group reclassification

Reclassified product groups	Equivalent product codes	
	SIC (Patents)	R&D and TBP
1 Railroad equipment	50	88.01
2 Agricultural chemicals	9	66.20 + 66.45
3 Water navigation vessels and equipment	49	88.30
4 Road transportation equipment	46 + 51	88.10
5 Aircraft and space vehicles	47 + 54	88.20
6 Drugs and medicines	14	66.10 + 66.15
7 Food and kindred products	1	62.01 + 62.10
8 Engines and turbines	23	86.01 + 86.05
9 Professional and scientific instruments	55	90.01 + 90.10
10 Petroleum and natural gas	15	64.15
11 Radio & TV equipment; electronic components	42 + 43	86.55 + 86.60
12 Office and data processing machines	27	86.25 + 86.30
13 Paints and allied chemicals	12	66.25
14 Rubber and plastics	8 + 16	68.01 + 68.05
15 Soaps, detergents and cosmetics	11	66.30 + 66.35
16 Textiles	2	76.01 + 76.10 + 76.20 + 78.00
17 Non-ferrous metal products	20	84.10
18 Inorganic chemicals	6	66.01
19 Organic chemicals	7	66.05
20 Ferrous products	19	84.01

TABLE 5. Employed index numbers

(a) R&D expenditures Wages and salaries	Consumer goods	Capital goods
Consumer price index for employees' families: GENERAL INDEX	Consumer price index for all consumers: NON-FOOD PRODUCTS INDEX	Consumer price index for all consumers: NON-FOOD PRODUCTS INDEX

(b) Technological balance of payments Receipts	Payments
Consumer price index for all consumers: SERVICES INDEX	Consumer price index for all consumers: SERVICES INDEX

Apart from this classification, which confirms the impression given by the visual analysis of data shown in Table 6, it can be stated that the use of different indicators generally gives different results for the technological growth of product groups. This was the case, for instance, for 'Agricultural chemicals', whose technological growth rates were 71·11% in the case of patents as an indicator, 10·74% in the case of R&D expenditures and −3·58% as far as TBP was concerned; or for 'Non-ferrous metal products' whose growth rates were, respectively, −19·76%, 49·88% and 77·07%.

4. Conclusion

This study points out that the most commonly used technological indicators, if compared, generally give discordant results as to the level of innovation growth. Thus, the several limitations that every indicator presents, which are largely acknowledged by some authors and have been partially outlined here, do not seem to be negligible. It can be stated that the adoption of a single indicator for the measurement of the technological growth rate is hardly acceptable, and no assertion about innovation levels can be made unless concordant information is obtained by various indicators.

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TABLE 6. Growth rates according to patents, R&D and TBP

Product groups[a]	Patents[b]			R&D expenditures[c]			TBP (balance)[c]		
	1981	1987	%Δ	1980	1986	%Δ[d]	1981	1987	%Δ[d]
1	8·02	21·22	164·59	8 487	26 430	211·41	−221	−656	−197·27
2	142·90	244·52	71·11	37 005	40 979	10·74	−2 625	−2 719	−3·58
3	9·83	16·66	69·48	15 418	43 217	180·29	−2 045	−2 935	−43·50
4	108·98	170·17	56·15	577 747	728 187	26·04	20 391	27 637	35·53
5	46·40	68·34	47·28	288 012	783 695	172·11	−4 912	122	102·48
6	200·92	286·90	42·79	371 579	657 901	77·06	−68 975	−34 858	49·46
7	27·00	37·25	37·96	14 902	39 160	162·77	−3 902	−7 222	−85·11
8	37·74	51·49	36·43	46 042	86 208	87·24	−8 494	−589	93·07
9	390·36	531·25	36·09	49 488	86 265	74·31	−8 784	−20 431	−132·59
10	15·50	20·42	31·74	71 001	72 137	1·60	−1 009	−1 711	−69·61
11	360·31	469·48	30·30	468 693	843 896	80·05	−38 769	−21 173	45·39
12	168·14	183·88	9·36	191 797	380 869	98·58	−236 783	−132 195	44·17
13	28·50	30·75	7·89	21 098	21 181	0·39	−6 532	−5 983	8·40
14	378·01	360·44	−4·65	245 867	242 569	−1·34	−40 225	−51 153	−27·17
15	20·58	18·50	−10·11	6 386	16 737	162·10	−63 749	−45 059	29·32
16	34·80	30·84	−11·38	44 351	44 151	−0·45	−26 378	−9 892	62·50
17	21·80	18·99	−12·89	22 254	30 630	37·64	−4 358	−2 415	44·58
18	127·67	102·44	−19·76	14 915	22 354	49·88	−12 314	−2 824	77·07
19	624·91	425·23	−31·95	55 645	61 518	10·55	−280	−1 550	−454·39
20	33·21	15·58	−53·09	73 742	98 759	33·92	−3 160	−5 497	−73·97

[a]For product group descriptions, see Table 4.
[b]Number of Italian patents registered in the USA; numbers may not be an integer since patents utilized in more than one sector have been equally shared.
[c]Millions of 1985 Italian lire.
[d]Growth rates were calculated from non-rounded values, so they may not exactly correspond to those obtainable from the rounded values shown.

TABLE 7. Decreasing lists of the technological indicators' growth rates

Patents		R&D		TBP	
% growth rate	Product group codes[a]	% growth rate	Product group codes[a]	% growth rate	Product group codes[a]
164·58	1	211·41	1	102·48	5
71·11	2	180·29	3	93·07	8
69·48	3	172·11	5	77·07	18
56·14	4	162·77	7	62·50	16
47·28	5	162·10	15	49·46	6
42·79	6	98·58	12	45·39	11
37·96	7	87·24	8	44·58	17
36·43	8	80·05	11	44·17	12
36·09	9	77·06	6	35·53	4
31·74	10	74·31	9	29·32	15
30·29	11	49·88	18	8·40	13
9·36	12	37·64	17	−3·58	2
7·89	13	33·92	20	−27·17	14
−4·64	14	26·04	4	−43·50	3
−10·10	15	10·74	2	−69·61	10
−11·37	16	10·55	19	−73·97	20
−12·88	17	1·60	10	−85·11	7
−19·76	18	0·39	13	−132·59	9
−31·95	19	−0·45	16	−197·27	1
−53·08	20	−1·34	14	−454·39	19

[a]For product group descriptions, see Table 4.

TABLE 8. Product group classification according to growth rate[a]

Growth rate	Patents	R&D	TBP
High	1 Railroad equipment 2 Agricultural chemicals 3 Water navigation vessels and equipment 4 Road transportation equip. 5 Aircraft and space vehicles 6 Drugs and medicines	1 Railroad equipment 3 Water navigation vessels and equipment 5 Aircraft and space vehicles 7 Food and kindred products 15 Soap, detergents and cosmetics 12 Office and data processing machines 8 Engines and turbines 11 Radio–TV equip.; Electrnc. components	5 Aircraft and space vehicles 8 Engines and turbines 18 Inorganic chemicals 16 Textiles 6 Drugs and medicines 11 Radio–TV equip.; Electrnc. components 17 Non-ferrous metal products 12 Office and data processing machines
Medium	7 Food and kindred products 8 Engines and turbines 9 Professional and scientific instruments 10 Petroleum and natural gas 11 Radio–TV equip.; Electrnc. components	6 Drugs and medicines 9 Professional and scientific instruments 18 Inorganic chemicals	4 Road transportation equip. 15 Soap, detergents and cosmetics
Static	12 Office and data processing machines 13 Paints and allied chemicals	17 Non-ferrous metal products 20 Ferrous products 4 Road transportation equip. 2 Agricultural chemicals 19 Organic chemicals 10 Petroleum and natural gas 13 Paints and allied chemicals	13 Paints and allied chemicals
Decreasing	14 Rubber and plastics 15 Soap, detergents and cosmetics 16 Textiles 17 Non-ferrous metal products 18 Inorganic chemicals 19 Organic chemicals 20 Ferrous products	16 Textiles 14 Rubber and plastics	2 Agricultural chemicals 14 Rubber and plastics 3 Water navigation vessels and equipment 10 Petroleum and natural gas 20 Ferrous products 7 Food and kindred products 9 Professional and scientific instruments 1 Railroad equipment 19 Organic chemicals

[a]The classifying ranges are shown in Table 9.

TABLE 9. Ranges used for classifying product groups

Classes	Growth rate ranges	
	Patents and TBP	R&D
High	>40%	>80%
Medium	20%–40%	40%–80%
Static	0%–20%	0%–40%
Decreasing	<0%	<0%

Notes

[1] This is particularly true for those small and medium-sized firms which do not have their own research laboratories and cannot make use of external ones.

[2] This is why patents obtained by individuals are often neglected and foreign patents (i.e., domestic inventions patented abroad), rather than domestic patents, are considered a good technological indicator. Indeed, foreign patents usually do not include less important inventions and the patents granted to private individuals are a low percentage and most of them are likely to actually be small firms' inventions [15].

[3] For a more detailed exposition of results, see ref. [34].

References

1 C. Freeman, Measurement of output of research and experimental development: a review paper. *Statistical Reports and Studies*, UNESCO, Paris, 16 (1969).

2 C. Freeman, *Recent Developments in Science and*

Technology Indicators: a Review. Science and Policy Research Unit (SPRU), University of Sussex, November 1982.
3 G. Sirilli, *Manual for Statistics on Scientific and Technological Activities.* UNESCO, Paris, 1980.
4 OECD, *Science and Technology Indicators I — Trends in Science and Technology in the OECD Area during the 1970s: Resources Devoted to R&D.* DOC.DSTI/SPR/81.27, Paris, September 1982.
5 CEE, *Nomenclatura per l'analisi ed il confronto dei programmi e dei bilanci scientifici (NABS).* EUROSTAT, Brussels, 1983.
6 EUROSTAT, *Il finanziamento pubblico della ricerca e dello sviluppo.* Luxembourg, 1973–1983.
7 ISTAT, Statistiche della ricerca scientifica. *Collana d'Informazione,* various issues.
8 UNESCO, *Guide to Statistics on Scientific and Technological Information and Documentation.* Paris, 1982.
9 N. Rosenberg, *Inside the Black Box: Technology and Economics.* Cambridge University Press, Cambridge, 1982.
10 D. Archibugi and G. Sirilli, Pubblico e privato nella R&S dei paesi industrializzati. *Politica ed Economia* (December 1985) 59–65.
11 M. Kamien and N. Schwartz, *Market Structure and Innovation.* Cambridge University Press, Cambridge, 1982.
12 L. Soete, Firm size and inventive activity: the evidence reconsidered. *European Economic Review,* 12 (1979) 319–340.
13 R. Kelly, *Alternative Measurements of Technology Intensive Trade.* US Department of Commerce, Washington, 1976.
14 G. Napolitano and G. Sirilli, The patent system and the exploitation of inventions: results of a statistical survey conducted in Italy. *Technovation,* 10 (1) (1990) 5–16.
15 D. Archibugi, The inter-industry distribution of technological capabilities. A case study in the application of the Italian patenting in the USA. *Technovation,* 7 (1988) 259–274.
16 G. Barbiroli, *Le dinamiche della tecnologia. Misure, analisi, modelli.* Bulzoni, Rome, 1991.
17 G. Sirilli, The technological balance of payments as an indicator of technology transfer in OECD countries. The case of Italy. *Technovation,* 11 (1) (1991) 3–25.
18 OECD, *Report on the Workshop on Technological Balance of Payments.* DOC.DSTI/SPR/82.9, Paris, February 1982.
19 OECD, *Experimental Studies on the Analysis of Output — Part 3rd: The Technology Balance of Payments.* DOC.DSTI/SPR/83.13, Paris, February 1983.
20 UIC, *Bilancia tecnologica dei pagamenti.* Ufficio Italiano Cambi, Rome, various issues.
21 ISTAT, Indagine sulla diffusione della innovazione tecnologica nell'industria manifatturiera italiana. *Collana d'Informazione,* 19 (1987).
22 A. Piatier, The use of surveys for evaluating innovation policies. *Workshop on the Evaluation of the Effectiveness of Government Measures for the Stimulation of Innovation.* OECD, Paris, June 1983.
23 Institut für Wirtschaftsforschung, *The IFO Innovation Survey — Conceptions and Results.* Munich, 1983.
24 SPRU, *Science and Technology Indicators for the UK. Innovations in Britain since 1945.* Science and Policy Research Unit, University of Sussex, Falmer, 1981.
25 Z. J. Acs and D. B. Audretsch, Innovation and firm size in manufacturing. *Technovation,* 7 (1988) 197–210.
26 R. Vernon, International investment and international trade in the product cycle. *Quarterly Journal of Economics,* 80 (1966) 190–207.
27 F. Pierelli, I mutamenti della struttura degli scambi mondiali e la posizione italiana. *Contributi alla Ricerca Economica,* Banca d'Italia, 16 (1983).
28 R. Leoni, Sulla definizione di industrie high tech tramite indicatori di input. *L'Industria — Rivista di economia e politica industriale,* 2 (1989) 247–276.
29 G. Amendola and A. Perrucci, Commercio internazionale e tecnologia: aspetti teorici e problemi di ricerca empirica. *Direzione Centrale Studi,* RTI/ST. ENEA, 3 (1988).
30 Istituto Nazionale per il Commercio Estero (ICE), *L'industria italiana nella competizione internazionale. I prodotti ad alta tecnologia,* ICE, Rome (1986).
31 D. Archibugi and M. Pianta, *The European Technological Specialization.* EEC, Brussels, December 1990.
32 C. Freeman, *A Review of some Recent Developments in Output Indicators for Science and Technology.* Science and Policy Research Unit (SPRU), Brighton, 1984.
33 F. Malerba and L. Orsenigo, *Technological Capabilities and Innovative Activities in the Evolution of the Italian Industry.* Università Commerciale 'Luigi Bocconi', Milan, working paper, 1986.
34 G. Valente, *Tecnologie strategiche ed effetti sulla dipendenza.* Degree dissertation, Faculty of Economics, University of Bologna, December 1990.
35 M. R. Spiegel, *Statistics.* McGraw-Hill, New York, 1975.

Andrea Raggi is a research fellow at the Istituto di Merceologia of the Faculty of Economics and Business Administration (University of Bologna). He received his degree in Business Economics from the University of Bologna in 1988. He has been carrying out research work on technological and economic aspects of production processes and objective methods to determine quality characteristics of products and resources.