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Review

PAVITT'S TAXONOMY SIXTEEN YEARS ON: A REVIEW ARTICLE

DANIELE ARCHIBUGI*

Consiglio Nazionale delle Ricerche, Via Cesare De Lollis, 12 – 00185 Rome, Italy

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Pavitt's taxonomy of innovating firms, published sixteen years ago, has become a classic paper in the field of technological change. This article discusses some of its characteristics and proposes some minor and not so minor extensions and revisions.

JEL classification: Technological change (O3); Innovation and Invention: Processes and Incentives (O31)

A fresh volume reprints thirteen papers that Keith Pavitt, Professor at the Science and Technology Policy Research Unit (SPRU) of the University of Sussex, has written or co-authored over the last fifteen years (Pavitt, 2000). Four of them are co-authored by his long-term partner Pari Patel. As expected, these papers provide a comprehensive overview of his research activity but, more broadly, also inform us about contemporary research on technological change which has departed from the standard views of neoclassical economics. Some of the fundamental contributions to our understanding of innovation have come from scholars who, like Pavitt, have no formal training in economics. Economics needed to import fresh blood from other disciplines such as engineering, management sciences, natural sciences, history and philosophy of science and knowledge to understand the determinants and impact of technological change.

* Correspondence author: Tel. +39–06–44879–211, Fax +39–6–4463836, email archibu@isrds.rm.cnr.it

Pavitt's methodological approach is strongly inductive and is based on empirical evidence and measured observations. His contribution to the field concerns both the pioneering of new measurement tools (most notably, innovation count surveys and patent statistics) and insights into the nature and determinants of innovative activities. The papers presented here are mainly problem-oriented and are generous with policy analysis and advice. Pavitt claims that this is somehow connected to the institutional environment where he has worked since the early 1970s, and in particular to the fact that SPRU main source of funding is contract research, with a time-horizon shorter than standard academic investigation. "My papers, he argues, do not derive a thought-out research strategy based from the outset of a well-established theoretical foundations. Life in a multi-disciplinary, policy-oriented research institute – which gets most of its funding through competing continuously for programmes, projects and contracts – does not leave much time for such deliberations, and even less, any inclinations" (p. ix). But I also suspect that this approach is congenital to Pavitt's intellectual attitudes and probably we should be thankful to the need to search for funding, if it induces the academic community to address issues which are relevant for the real world and understandable to policy makers and not only to a small circle of the converted.

In the acknowledgements, Pavitt cites a British mentor and an American mentor: Chris Freeman and Richard Nelson. If we compare Pavitt's writings to Freeman's, we note that the former is less dependent from the Schumpeterian legacy and independent from the Marxist one. In comparison to Nelson, Pavitt is more eclectic and not strictly confined within the evolutionary economics framework. Pavitt has in many regards been a free rider across disciplines and schools. But it is certainly significant that a very important – today the most important – part of innovation studies has found its space and audience in the no man's land between the borders of strictly defined disciplines. Chris Freeman, Richard Nelson, Nathan Rosenberg, Mike Scherer, Paul David, Stan Metcalfe, Bengt-Åke Lundvall, Luc Soete, David Audretsch, Cristiano Antonelli, Giovanni Dosi, Franco Malerba and Pavitt himself are now a well established cluster of scholars who have become dominant in the field because they have chosen to depart from received theory whenever this was unable to provide useful insights into the real world.

Pavitt's single most significant contribution to the economics of technological change is his taxonomy of innovating firms. Since it was firstly

published in *Research Policy* in 1984, this taxonomy has had a remarkable impact, has been applied to different countries and aspects and has inspired intellectual investigation, data collection and policy action. I wish to use this opportunity to comment on it.

THE NATURE OF PAVITT'S TAXONOMY

Although the words "category" and "taxonomy" are almost synonyms, they are very different in age. As early as 2,300 years ago, the father of all taxonomies, Aristotle, often used, the word "Kathegoría". The word taxonomy is, on the contrary, a recent one, dating to the first half of the eighteenth century. It was used by several scholars, including Linnaeus, to classify minerals and animal and botanical species. The scientists and philosophers of the Enlightenment introduced this neologism by recovering an ancient Greek word (táxon, arrangement, array) and associating it to nómos (law). Since then the word has been very successful and is still used in life sciences to classify species and minerals. It should be noted that the term flourished in the natural sciences a century before Charles Darwin proposed his theory of evolution, though in more recent times taxonomies have tried to describe and explain the static characteristics of objects as well as their evolving patterns. Over the last decades, the word has also been imported in social sciences.

Taxonomies are meant to classify phenomena with the aim of maximising the differences among groups. While, for example, "classifications" are often highly disaggregated, both in natural and social sciences, a "taxonomy" is considered useful, if it is able to reduce the complexity of the population studied into easily recallable macro-classes.

Industrial economics has for a long time subdivided productive activities into classes: typical examples are the grouping of firms according to their size and the nature of their main products. But many other classifications have been attempted for other purposes, such as the distinction between producers of durable and non-durable products, consumption and investments goods, and so on. The taxonomy presented by Pavitt has a different purpose from the previous classifications since it is devoted to classifying firms on the grounds of their technological competence. Pavitt's taxonomy is competing with (and has often replaced) another technology-based clas-

sification which has long been very popular; namely the grouping of industries according to their R&D intensity (e.g. high, medium and low R&D-intensive industries).

THE CATEGORIES OF THE TAXONOMY

Pavitt intended the taxonomy to describe the behaviour of innovating firms, to predict their actions and to suggest a framework for policy analysis. When it was first presented, the taxonomy was composed of four main categories. The first was supplier dominated firms active in traditional industries such as clothing and furniture (i.e. firms which innovate by acquiring machinery and equipment). The second was specialised suppliers of capital goods and equipment who live in symbiosis with their customers. The third was science-based firms born to exploit new scientific discoveries in fields such as electronics, chemicals, pharmaceuticals and aerospace, where the main source of knowledge is associated with in-house R&D laboratories. The fourth was scale-intensive firms active in mass production industries.

In subsequent versions (see, for example, in this volume, the paper "What We Know about Strategic Management of Technology", originally published in 1990), Pavitt has added another category to classify the emerging information-intensive firms, which have their main source of technological accumulation in the advanced processing of data and are typical in sectors such as banking, retailing and tourism. Unfortunately, and in my opinion unwisely, this has led to the disappearance of one of the former categories; namely specialised supplier firms. According to Pavitt's latest thoughts, these firms are somehow forced to become information-intensive or scale-intensive or to become non-innovative: "We have also excluded a `supplier dominated' trajectory since...it leaves accumulated technological skills and strategic initiative with suppliers. Firms intending to move from this position try to adopt either scale-intensive strategies (e.g. certain textile firms), or information-intensive strategies (e.g. certain retailing firms)" (Pavitt et al., 1989, p. 96–97). My own view is that supplier-dominated firms have a distinctive and significant technological trajectory and can be equally innovative by acquiring machinery and capital equipment. The Italian case well illustrates the phenomenon (see Archibugi et al., 1991; Evangelista et al., 1997).

DISCUSSING PAVITT'S TAXONOMY

The taxonomy has still many sides which can be fruitfully explored. I will mention here five critical areas which deserve further analysis.

First, as already mentioned, Pavitt's taxonomy is devoted to classifying innovating firms only and it does not cover non-innovative firms. How important are non-innovating firms in the economy? In a dynamic economy and in the long run, all firms are somehow forced to innovate or to perish. But, as stressed by a growing literature (see for example, Geroski et al., 1997; Malerba and Orsenigo, 1999), the intensity and persistence of innovation in firms varies greatly. According to the new data generated by the Community Innovation Survey (a source which, so far, has not been systematically exploited by Pavitt), the share of firms which introduce innovations over a three year-period varies according to the country considered and to the survey methodology implemented, from 35% to 80% (OECD, 1999). Such a high variety require additional efforts, especially to clearly define what is a "technological innovation". But it would be very significant to relate this evidence to each individual category of the taxonomy. This will help policy makers and business strategists to understand what should be done in order to allow more firms to innovate regularly.

Second, the taxonomy is devoted to classifying firms and not industries (by industry I mean the standard criterion of industrial economics, namely an aggregation of firms with similar output). Unfortunately, Pavitt himself has failed to make this aspect clear: in his 1984 article, as well as in his further developments, Pavitt has grouped in each category of his taxonomy data at the *industry* and not at the *firm* level. This is a major limitation since it is well known that firms which have for convenience been grouped together into an industry on the basis of their main output may have a very different technological base: both slippers and moon-boots belong to the footwear industry, but the technology-intensity of the two products is very different and it is reasonable to expect that their manufacturers will use different sources to innovate. In the introduction to the volume, Pavitt rightly notes, about his taxonomy that "its weakness is the high degree of variance still found within each category" (p. xi), but it is also likely that, if applied to the firm level, the variety within each category will be smaller.

Mine is more than a pedantic remark: a technology-based classification of firms loses much of its relevance, if it is applied to firms after they have

been aggregated into industries according to an output-based classification. If a technology-based classification is needed, it should be independent from other criteria. Figure 1 reports the two ways of grouping the individual units, e.g. firms, into the categories of the taxonomy. Part A reports the method most widely used: firms are firstly attributed to an industry according to the typology of their main product, and subsequently the whole industry is attributed to a class of the taxonomy. Of course, this method is not fully accurate: not all chemical firms deserve to be labelled as "science based", and vice versa, some firms belonging to the footwear industries might have a substantial technological basis. This method can be even lead to wrong policy advise; suppose that a government, convinced by Pavitt's taxonomy, will makes an attempt to foster innovation by using different incentives for each group of firms. If selectivity criteria are applied on the basis of the product industry to which a firm belongs it is likely that a substantial part of the incentives to innovation will be misplaced: for example, moon-boot manufacturers may receive incentives to purchase specialised machinery rather than to finance their in-house R&D.

Part B reports the method which should be used. Firms are directly attributed to a category of the taxonomy according to their intrinsic characteristics such as the rate and direction of technical change and their sources of innovation. In this case, Pavitt taxonomy will provide a categorisation of firms entirely independent from the product-based one. Hopefully, over the next few years more statistical and econometric work will be carried out to group firms, as opposed to industries, into the taxonomy's categories. A convincing beginning has already been attempted by Cesaratto and Mangano (1992).

Third, the existence of multi-product and, above all, multi-technology firms will make it difficult to classify some corporations into any of the categories indicated by Pavitt. Companies like IBM, General Motors, and Toshiba are likely to follow a variety of technological trajectories. In fact, a substantial part of Pavitt's recent research has been devoted to map and interpret the technological trajectories of these gigantic firms (see, in this volume, chapters 5 and 6). The evidence reported on the differentiated technological competencies of these firms suggests that further investigation needs to be made on how they should be included into the taxonomy.

Fourth, several scholars have applied revised versions of Pavitt's taxonomy at the product rather than at the firm level. Guerrieri (1999), for example, has applied a modified version of this taxonomy to international

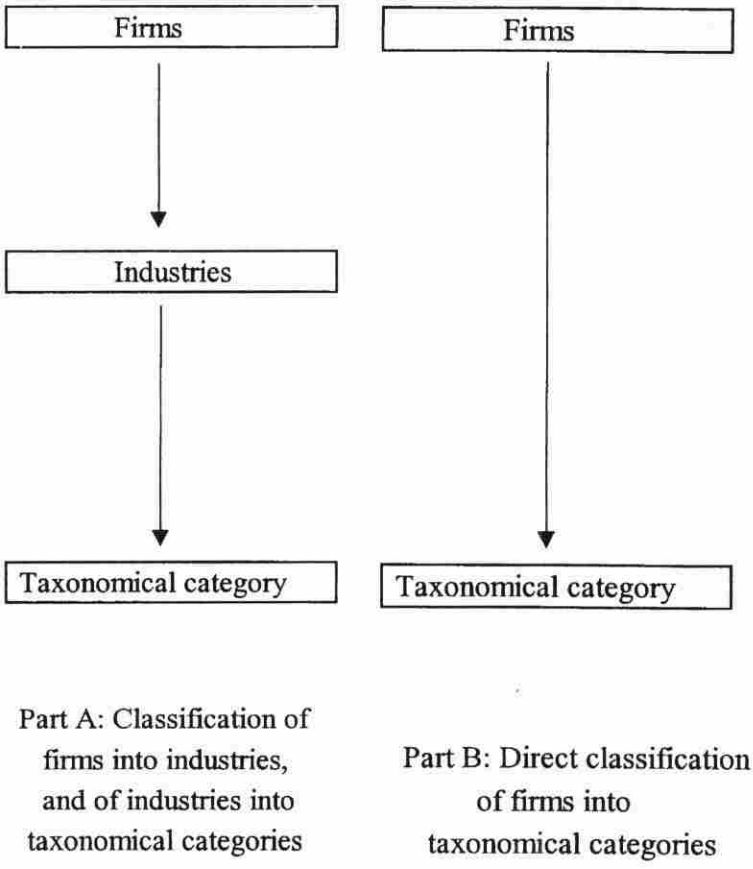

FIGURE 1 Classifyng firms into Pavitt's taxonomical approach

trade data. More than an extension, this is a transfiguration. But even in this version the taxonomy has proved to be vital. It should however be discussed how the same taxonomy applied at the product level interacts with the taxonomy applied at the firm level.

Fifth, the first applications of Pavitt's taxonomy were conceived for the manufacturing industries. But the same classification can easily been expanded to cover innovation in the service industries. Evangelista (2000) has shown that the most relevant differences between innovation in manufacturing and services is the role of software and the predominance of

user-producer interactions in the latter industries. He has further extended the taxonomy by adding a category of Interactive & Information Technology based companies. It is now possible to generate a single taxonomy of firms to include both the manufacturing and the service industries. Hopefully, this will help us to understand the similarities and differences between the innovative activities of the service sector, a topic about which, in spite of a significant stream of recent research, we still know much less than about manufacturing. But it will probably emerge that, from the technical change perspective, the difference between services and manufacturing is now blurred and that the two fields are becoming fully integrated.

THE EVOLVING CHARACTERISTICS OF THE TAXONOMY

Like many other classifications, a taxonomy is static rather than dynamic. But technological change is intrinsically a dynamic process: how can this taxonomy help us to understand economic evolution? In my view, it helps us a great deal to understand when technological change takes cumulative paths and when, on the contrary, it has a revolutionary nature. Certain firms introduce mainly incremental innovations, often induced by their suppliers, while others continuously search for new products and processes to conquer new markets. Once it is acknowledged that the variety of innovative behaviour is substantial, it becomes easier to explore how the different economic units are interconnected and to identify the main knowledge flows and user-producer linkages. This allows us, for example, to predict that technological developments in specialised supplier producers will be mainly cumulative and heavily dependent upon the demand from the firms they supply (which makes innovation in these firms demand-pull), while science-based firms will try to push forward the frontier of technological knowledge in their in-house labs (making their innovations more likely to be technology-push).

The same taxonomy, however, can also be read dynamically. On the one hand, it informs us of the technological trajectories followed by firms at present; on the other, it suggests that the history of capitalism has progressively created groups of firms with a peculiar way to introduce innovations. It is certainly significant that each category of firms can be associated with a long wave of economic development (see Freeman,

1987). The separation between supplier-dominated and specialised suppliers firms can be dated back to the first industrial revolution when, as Adam Smith predicted and described, a significant division of labour occurred between consumer goods and capital goods producers.

Scientific discoveries in the field of chemistry and electricity opened up new business opportunities which were quickly exploited by a generation of new firms. They grew in size much more than other firms and were the first to systematically exploit the fruits of scientific investigation by financing in-house R&D laboratories. The next wave was represented by new complex products for mass consumption, based on cost-cutting trajectories. Taylorism and Fordism, which underpinned post-war expansion, are associated with large and heavily organised firms whose competitive advantage is based on economies of scale and which correspond to the scale-intensive category of the taxonomy. Finally, the current technological developments of the so-called new economy correspond to the rise of information intensive firms active in both the manufacturing and the service industries and based on the intensive analysis and use of data-processing.

In this perspective, Pavitt's taxonomy helps us to understand that every long wave of capitalist development has generated a different typology of innovative firms. Figure 2 compares the categories of Pavitt's taxonomy with the long waves identified by his mentor Chris Freeman: the two categories, developed for very different purposes, match very well. The rise of a new category of firms has not led to the destruction of pre-existing firms. Capitalism has not destroyed pre-existing organisational forms, but it has added new ones. Schumpeterian gales of creative destruction have forced traditional firms to introduce many changes, but they have continued to follow the principal technological trajectory that they were already accustomed to. This has allowed them to continue to co-exist with new firms characterised by a different technological trajectory.

But, of course, the quantitative and qualitative importance of each group of firms has considerably changed within capitalist evolution: supplier-dominated firms have progressively reduced their share of output, while other firms have progressively taken on a greater role in the economy. This suggest that the same taxonomy may also be used to explore the parallel long-term evolution of corporations and of economic activity. Economists studied how societies have evolved by considering the distribution of economic activity among agriculture, manufacturing and serv-

Period	Successive Techno-Economic Paradigms	Industrial organisation	Typical industries	Rise of Pavitt's category of firms
1770-1830	Early Mechanisation	Growing importance of small manufacturing firms	Textiles, Potteries, Machinery	Supplier dominated
1840-1880	Steam power and railway	Separation been producers of capital and consumption goods	Mechanical engineering, Steel and Coal	Specialized suppliers
1890-1930	Opportunities associated to scientifc discoveries	Emergence of large firms	Chemicals, Electrical machinery, Engineering	Science based
1940-1980	Fordist and Taylorist revolutions	Oligopolistic competition for mass consumption	Automobiles, Synthetic products, Consumer durables	Scale intensive
1990-	Information and communicaiton	Networks of firms, strong user-produces interactions	Microelectronics, Telecoms, Software	Information intensive

Source: Author's Elaborations on Freeman (1987), Table 15.

FIGURE 2 Phases of Capitalist Development and Pavitt's Categories of Firms

ices. Today, it might be more relevant to study how employment and value added is subdivided among the categories of Pavitt's taxonomy and how this evolves over time.

CONCLUSION

Pavitt's taxonomy of innovating firms is his most significant contribution to the study of technological change. Though it has had a remarkable impact over the last sixteen years, its potential is far from being exhausted. In order to increase its usefulness, however, some key methodological issues still need to be clarified. This taxonomy, like the majority of classifications, came into being for a static purpose, though it can easily be used at the dynamic level to explore the evolution of innovative firms.

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