Why Patterns of Technical Change Differ: Further Steps Towards an Integrated Typology

Paul Nightingale, Roger Miller, Joe Tidd and Mike Hopkins

Abstract
This paper provides an explanation of the very diverse patterns of innovation found in manufacturing and services. It argues that what appears as confusing complexity is actually the outcome of a simple process involving technical change, the division of labour, and the effective utilisation of specialised resources. This process has generated a cumulative differentiation between a) users and producers of machinery, b) firms using standard process machinery and firms developing scale-intensive production systems, c) design and science intensive product innovators, and d) various systems integrators and systems users. The increasing economic importance of large technical systems has generated a decline in the importance of personal services, while increasing the importance of professional services, and making the provision of manufacturing related service solutions more important. The resulting dynamic typology is explored using data on the innovative practices of 950 international firms. Managerial and policy implications are discussed.

Introduction

> "All the improvements in machinery, however, have by no means been the inventions of those who had occasion to use the machines. Many improvements have been made by the ingenuity of the makers of the machines, when to make them became the business of a peculiar trade; and some by … those who are called philosophers ... In the progress of society, philosophy or speculation becomes, like every other employment, the principal or sole trade and occupation of a particular class of citizens. Like every other employment, too, it is subdivided into a great number of different branches, each of which affords occupation to a peculiar tribe or class of philosophers; and this subdivision of employment … improves dexterity, and saves time. Each individual becomes more expert in his own peculiar branch, more work is done upon the whole, and the quantity of science is considerably increased" (Adam Smith *Wealth of Nations* 1776:16)

1.1 Purpose

The subject matter of this paper is why patterns of innovation and technical change differ. It develops and explores an inductive typology that attempts to explain why innovation patterns change over time. In doing so, the paper integrates previous work on manufacturing and service innovation, to produce a dynamic theory of their changing interactions.

The diverse patterns of innovation found in industry was shown in Pavitt's (1984) seminal taxonomy paper and since then a large body of research has clarified its extent. Because Pavitt's original data only covered a subset of innovative activity (Gallouj, 2001), this research has expanded the original taxonomy, possibly to the extent it now confuses more than it clarifies. In this paper, we reassess this research and suggest that the static snapshot nature of the data that is often used overemphasises complexity and obscures an underlying pattern of change that can be seen when these snapshots are put in temporal order. While the original data in the 1984 paper was imperfect, a careful reading shows Pavitt recognised this and anticipated its implications. Moreover, his theory can explain these new patterns of innovation and indicate biases within new datasets.

The argument of the paper can be summarised as suggesting that the diversity of innovation found within the empirical data is the result of changing divisions of labour and increasing use of complex technological systems leading to organisational specialisation. Taking a long historical overview (Archibugi, 2001): the nineteenth century saw the emergence of new a division of labour between specialised capital goods suppliers and supplier dominated firms (Rosenberg, 1966; 1968); the twentieth century saw these new capital goods used to develop systems for scale intensive production based on process innovations (Chandler, 1990). Some of the resulting large firms developed R&D departments with science intensive patterns of innovation (Mowery, 1983). Since the late 1970s, further divisions of labour in the *production* and *operation* of these systems has seen the emergence of systems integrator, integrated solutions providers, and a range of service and manufacturing firms supported by software-intensive capital goods (Hobday 1998).

During this process the boundary between manufacturing and service provision has been primarily (but not exclusively) determined by managerial and economic factors related to the relative utilisation, under different ownership conditions, of the productive capacity (both technological artefacts and operational knowledge) needed to perform a service. Following Gershunny (1984) as consumer goods (produced *by* improving capital goods) have increased in quality and *decreased* in price (Rosenberg, 1970), there has been a decline in personal services as households use consumer goods to produce services at home. Similarly, as production systems (made *of* new capital goods) *increase* in complexity, cost and scope (Nightingale *et al*, 2004) knowledge intensive professional services have become more important. Moreover, service provision has increasingly become a complementary asset (Teece, 1986) for firms producing and operating these complex technical systems (Davies et al 2005) because it allows more value appropriation and better utilisation of high-fixed cost assets. This simple historical explanation can be used to populate a series of innovation typologies for particular periods of time which can then be empirically tested to produce taxonomies of innovation patterns.

This is illustrated using new data from a detailed survey of the innovative practices of 950 international firms. The data is used to extend the theory by showing in greater detail how patterns of innovation are structured around a relatively small number of forms continuing a move away from sectoral models of firm best practice to meso-level articulations of 'rules' that influence success. In describing these changes we hope to provide a more rigorous empirical and theoretical basis for understanding what technological capabilities are and what internal logics they follow in given strategic contexts.

In particular, these taxonomic categories help make explicit the endogenous nature of technical change and the substantial variety in its forms, allowing analysts and policy makers a more nuanced framework for analysis than the current, potentially very misleading, focus on R&D intensity. We explore this point in the conclusion. The next subsection discusses the data, while section 2 reviews the literature on patterns of innovation to provide a comprehensive overview of changes. Section 3 introduces our new data. While section 4 provides a theoretical explanation that integrates both services and manufacturing. The final section discusses implications for theory and practice.

1.2 Approach, Data Provision and Structure

Data is based on a very detailed questionnaire conducted as part of the MINE research programme. The data was collected from 950 CTOs or VPs of R&D using both written and on-line survey tools. The survey tool can be viewed and downloaded at the following address www.minesurvey.polymtl.ca with XXXX as the code and password. The survey tool was designed by Serghie Floricel with participation from Roger Miller and includes 423 items grouped into seven blocks that address: contextual conditions, innovation capabilities, competitive advantage, strategies and investments in innovation, organisation and networking, innovation management practices and performance. As with original SPRU dataset the sampling was sector driven and sought to address 20 innovative sectors. The quantitative data is supported by some 200 interviews between 1 and 2 hours long with on average 3 interviews per firm, as well as interviews with regulatory agencies, industrial associations and support firms. All interviews were recorded and transcribed.

The data was clustered independently of the theory development and the methods are discussed in previous publications Floricel et al 2006. As the discussion will highlight, there are still substantial gaps with both the data and theory, but many of those gaps are exactly ones that we would anticipate from both the theory we develop and from well known methodological deficiencies in the data. To enable our work to be critiqued and developed further we have included the full MINE data set and research instruments with this publication and they are both available via the Research Policy website.

2. Patterns of innovation within and between sectors

2.1 Patterns of Innovation – Pre-Pavitt

A defining feature of innovation is that it changes over time (Smith 2004). This diversity was picked up in a series of studies (Rothwell, 1975; Rothwell et al 1973; 1977) and in particular in Freeman's (1979) inductive taxonomy that divided manufacturing innovation into three groups: In the first, innovation was directed towards design and the development of superior products. This included aircraft and aero-engines, electronics and electrical goods, vehicles, instruments, chemicals and machinery. The second group comprised basic materials, such as stone, metals, glass and paper and innovation was mainly directed towards cost reduction through factor-saving. The third group was mainly consumer focused products such as textiles and apparel, furniture, and manufacturing not covered previously. In this group innovation focused on design, fashion and advertising rather than technology.

Nelson and Winter (1977) conceptualised these different patterns in terms of technological trajectories based on the differential and cumulative nature of technological knowledge (see also, Sahal, (1981), Dosi (1982), Freeman et al (1982), Rosenberg (1976, 1982), Gold (1979)). Different processes for generating, screening, and diffusing innovations generate distinct patterns of technical change based on their a) sources of technology, b) user's needs, and c) ability to appropriate the returns to innovation (Nelson, 1980). Similarly, Dosi (1982) characterised trajectories by a) learning processes, 2) sources of knowledge and 3) whether it was science or engineering. Freeman's (1982) long wave theory positioned the emergence of these patterns of innovation in historical time, producing, as Archibugi (2001) showed, an implicit historical typology that maps onto the Pavitt taxonomy (see table 1).

This historical typology fits with recent economic history. For example, a key feature of late 19th century innovation was the emergence of large firms with *scale intensive* production and distribution systems (Chandler, 1977). Their development required process innovations that integrated the products of design-intensive *specialised suppliers* of capital goods (Rosenberg, 1966; Scranton, 1984) who exist in symbiotic relationships with their customers. Flows of technology from these specialised suppliers also supported the gradual mechanisation of *supplier dominated* industries (David, 1975) and in the early 20th century provided instrumentation to the R&D laboratories of firms in *science intensive* sectors (Schumpeter, 1934).

Consequently, by 1984 the basic empirical and theoretical building blocks of Pavitt's taxonomy were in place. Some sectors focused on process innovations, largely done by in-house production engineers (Chandler, 1977). While others focus on product innovations, that divided into ones based on design and close interaction with customers and ones involving research and close links to public science (Rothwell, 1975).

Table 1. Freeman's (1982) Kondratiev waves after Archibugi (2001)

Number and timing	Emergence of Pavitt Taxonomy	Main sectors and infrastructure	Organisational problems and solutions	Organisations
First Early Mechanisation 1770s-1840s	Supplier Dominated	Textiles, Iron work Trunk canals Turnpike roads	Limits of putting out system & hand operated tools. Factory system and small scale mechanisation	Individual entrepreneurs, small firms, partnerships
Second Steam and Railways 1840s-1890s	Specialised Supplier	Steam engines Machine tools Railways, shipping	Limits of water power and small markets Application of coal based energy	Emergence of large firms. Limited liability and joint stock companies
Third Electrical and Heavy Engineering 1880s-1930s	Scale intensive	Electrical & heavy engineering, heavy chemicals Electrical distribution	Limitations of iron and pulley mediated steam power Steels, alloys, decentralised electrical power	Large firms, cartels and trusts. Regulation of natural monopolies. Emergence of middle management
Fourth Mass Production 1940s-1980s	Science Intensive	Automobiles, process plant, synthetic materials Airlines, Highways	Limitations of batch production Flow based mass production, standardisation	Oligopolistic competition, multinational corporations, vertical integration
Fifth ICT 1980s-	Information intensive	Computers Telecommunications Finance	Inflexibility of standardised mass production. Flexible production	Networks of large firms and small firms

2.2 Patterns of Innovation–Pavitt's Taxonomy

Pavitt's (1984) taxonomy paper fitted these components together using data from the SPRU-Database of British Innovations (Townsend et al 1981) that showed that:

> "Innovating firms in electronics and chemicals, are relatively big, and develop innovations over a wide range of specific product groups within their principle sector, but relatively few outside. Firms principally in mechanical and instrument engineering are relatively small and specialised, and they exist in symbiosis with large firms, in scale intensive sectors like metal manufacturing and vehicles, who make a significant proportion of their own process technology. In textile firms, on the other hand, most process innovation comes from suppliers." (Pavitt 1984).

This empirical diversity was used to produce Pavitt's fourfold taxonomy of:

Supplier Dominated firms which are found in traditional sectors of manufacturing, construction, agriculture and lumber, paper, printing and publishing and professional and other services. Such firms tend to be small, as they non-technical forms of appropriation such as professional skills, trademarks and advertising. They typically focus on cost-cutting and receive their process technology from supplier firms.

Scale Intensive firms use process technology to increase the scale and speed of production to generate economies of scale. Their products tend to be price sensitive and include mass production vehicles and consumer goods, materials and some information intensive services (Pavitt, 1984:364). Because these sectors rely on firm-specific production technologies a substantial amount of innovation is undertaken within their production engineering departments. Such firms typically appropriate a substantial amount of value and grow to be large and often oligolopolistic.

Specialised Supplier firms have a symbiotic relationship with their scale intensive and supplier dominated customers who they supply with specialised machinery, instrumentation and services. Their customers often provide new product ideas based on their operating experience and demand high performance products that typically have an important impact on their production efficiency. Firms tend to be small and rely on batch production.

Science Intensive firms are found in chemicals and electronics and rely on R&D as the main source of their innovations, typically rapidly developing basic research conducted in universities. Their scientific and technological sophistication creates substantial barriers to entry and allows firms to grow large by appropriating a large proportion of the value of their innovations, typically through patents, secrecy, scale of production.

The paper explained these differences by stressing that technical knowledge 'is specific to firms and applications, cumulative in development and varied amongst sectors in source and direction.' (1982:343). Diverse patterns of innovation emerge as firms respond to their customers' demands and accumulate firm and sector specific capabilities at different rates and in different areas of technological knowledge.

Together the taxonomy and theory explained a number of anomalies within the literature of the time related to the relative importance of different sized firms and the role of science and market demand in innovation. Despite these contributions Pavitt was not fully satisfied with either the theory or the data and highlighted areas where further support was needed. In particular, the substantial diversity within each category suggested the need to move to firm level data. Secondly, the static model and snap-shot data failed to fully capture the dynamics of innovation. Thirdly, the data was very poor at picking up software, incremental innovations, design, and services. In the conclusion Pavitt (1984:370) also drew attention to how innovation in infrastructure was overlooked and for the taxonomy to be more comprehensive an additional 'category should be added to cover purchases by governments and utilities of expensive capital goods related to defence, energy, communications and transport'.

Thus the original Pavitt taxonomy might be more correctly described as a five fold taxonomy covering (i) supplier dominated (SD), (ii) specialised suppliers (SS), (iii) scale intensive (Sc), (iv) science intensive (Sci) and (v) complex infrastructure and systems (CoPS) (see table 2).

Table 2: The Pavitt (1984) Taxonomy

Category of firm	Price performance bias (customer)	Innovation Trajectory	Value capture and appropriation trade offs	Source of process technology	Size of innovating firm	Example firm
Supplier dominated	Price	Cost cutting process	Buy process technology from suppliers, invest internally	Suppliers, large customers research services	Small – limited ability to appropriate value	transport, bakeries, farming, cleaning services, security
Scale intensive	Price	Cost cutting process	systems and generate speed, scale & scope economies	In house production engineering, suppliers of capital goods,	Large – able to exploit scale and scope economies	Traditional telecoms, industrial gases, bulk materials, paper mills
Science based	Both	Research intensive product/service innovation (appropriate scale/IPR)	Patenting, marketing, R&D know-how, regulation, scale-up production, access external research, manage uncertainty	Suppliers & in-house depending on scale and product-process interactions	Depending on ability to appropriate returns from small to very large	Pharmaceuticals, biotechnology, chemicals
Specialised supplier	Performance	Design/knowledge focused high performance products and services	Reconfiguration of professional knowledge, design capability, user interactions, patents	In house - organisational, suppliers	Small	Speciality chemicals, professional services
Complex Capital Goods (CoPS)	Performance	Design/knowledge focused high performance products and services	Project management skills; reputation; Reconfiguration of professional knowledge, design capability, user interactions,	In house – project management, ability to co-ordinate external suppliers	Large	Aerospace, infrastructure, defence, telecommunications

2.3 Patterns of Innovation – Taxonomies after Pavitt

In Pavitt (1990) a category of '*information-intensive*' firms (and sectors) was added where technological accumulation involved the development of software, computer systems and organisational procedures for processing data (see Pavitt et al 1989). This category is similar to the scale intensive category and includes tourism, banking and retailing. Pavitt (1990) also suggested the supplier dominated category was declining as firms moved into the scale intensive and information intensive categories.

These changes were reviewed in Archibugi (2001) who pointed out that the original taxonomy, while extremely useful, overlooked firms that were innovative in both products and processes. In particular, multi-technology firms in design intensive sectors (MTF-D) such as car production, and science intensive sectors (MTF-Sci) such as chemicals and electronics have capabilities in both product and process technologies. Archibugi (2001) also suggested supplier dominated firms remain economically important and that the inclusion of a non-innovative category would better reflect the real economy, although the extent to which a firm is non-innovative or supplier dominated may depend on the time period in which it is evaluated.

Further empirical work has tended to be supportive of the taxonomy (Ana, Variantruios, Storper and Salais (1997)). Marsili (2001) provided an important extension by integrating US R&D and European PACE survey data to produce a taxonomy of regimes of technological knowledge that divided into:
A *Science-based* regime where firms had knowledge bases in life sciences and physics. Such firms had high levels of technological opportunity, high technical barriers to entry, and very cumulative innovations. Innovation is typically product focused and builds on academic research showing clear similarities to Pavitt's science intensive category.
A *Fundamental-processes* regime associated with chemicals and petroleum, where firms have a moderate level of technological opportunity, and high barriers to entry related to scale advantages (rather than knowledge). Innovation focuses on process improvements and draws on affiliated firms, users and academic research. This regime is similar to Pavitt's Scale intensive category but more science intensive.
A *Complex (knowledge) system* regime that combines mechanical, electrical/electronic and transportation technologies, of the sort found in the aerospace and motor vehicles industries, has medium-high levels of technological opportunity, and barriers to entry in both knowledge and scale production.
A *Product-engineering* regime that draws on mechanical engineering technologies, has a medium-high level of technological opportunity, and low barriers to entry. Innovation is mainly product based and draws on knowledge from users, showing similarities to Pavitt's specialist suppliers.
A *Continuous-processes* regime is found in metals, paper, food, building material and chemicals and combines a range of sources of knowledge about production from chemical/metallurgical processes, mechanics and control. The regime is generally characterised by low technological opportunities, and is similar to Pavitt's scale intensive category.

Marsili's taxonomy shows important changes in the economy and its measurement since Pavitt's paper and adds additional insight by dividing scale intensive firms into fundamental processes (that draw on chemistry and life-sciences) and traditional continuous process firms, as well as showing how the complexity of the underlying knowledge distinguishes between the aerospace and vehicles industries (Marsili and Verspargen 2001:12, see De Jong and Marsili (2004) for an extension of this work to Dutch SMEs).

2.4 Patterns of innovation in complex production and infrastructure systems

The validity of Marsili's differentiation of simple and complex products has been shown in a substantial body of research on large technical systems and their components (Walker, 1990; Hobday, 1998; Davies, 1996; Davies et al 2005, 2006; Pavitt, 2000; Brusoni et al 2001; Brady and Davies, 2001; Acha, et al. 2004; Flowers, 2007). These complex systems now provide much of the infrastructure underpinning modern economies (Best, 2001), yet are poorly captured by traditional innovation statistics. Their components, termed complex product-systems or CoPS, are more expensive, complex and incorporate more *embedded software* than traditional capital goods produced by specialist suppliers (Hobday, 1998; Nightingale et al, 2003).

The costs, complexity, long development times, of these products, together with the need to match complex customer requirements (Rush, Bessant and Hobday, 2001) increases uncertainty (Hobday, 1998) with important organisational consequences (Hobday, 2000; Nightingale, 2000). Marketing and sales typically happen before production starts, and R&D and production tend to be integrated (Hobday, 1998). Production is project based and is organised around temporary networks of suppliers, with a high-level systems integrators (SI) liaising with and advising clients. These system integrators engage in high-level architectural design which is customised to carefully match regulators' and customers' requirements. The design is then decomposed into a hierarchy of increasingly less complex systems, sub-systems and components (Walker, 1988; Hobday, 2000; Prencipe, et al 2001) with a large proportion of production, and typically a lower proportion of lower level design, outsourced to webs of suppliers.

The limited market and bespoke nature of design, (compared to traditional consumer goods), constrains firms' ability to move beyond craft or batch production (Hobday, 1998; Gann, 1988). While production is rarely scale intensive, it has to be innovative and can be high-value added. This is because the systemic connections between these components makes designs fragile, as changes in one component can lead to changes in others, potentially creating very costly redesign feedback loops (Nightingale, 2000). These feedback loops add to the time taken to complete a project and complicate its co-ordination, making project management and attention to risk more important (Prencipe, et al 2001). This is particularly the case with embedded software, which now is used to co-ordinate systems behaviour and is a major source of project failures and overruns (Flowers, 1994; Brooks, 1995).

Co-ordinating the outsourced production of systemically interconnected components requires SI to "know more than they do" (Brusoni, et al 2001) as SI not only assemble product components, they also design the overall system; assess, select, co-ordinate and test components from a network of external suppliers; integrate those components into functioning systems; build up the knowledge required to operate, upgrade and decommission those systems while they are in use; and develop the capabilities needed to produce future generations of technology (Davies, et al 2007). This production system generates distinct sub-categories with their own patterns of innovation:

CoPS are the high cost, high complexity, software intensive components of these systems. As capital goods they are sold business to business typically organised around projects (Davies and Hobday, 2006) in which development and manufacturing are integrated and marketing and contract signing occurs before production (Hobday, 1998).

Systems Integrators (Brusoni et al 2001, Pavitt, 2001, Davies et al 2006 ; Best, 2000) can be defined as 'prime contractor organisations responsible for the overall system design and integration of product and service components supplied by a variety of external suppliers into a functioning system' (Davies et al 2007:184). They are responsible for integrating components (CoPS) into operational systems, typically providing a full range of services related to financing, project management, training, operation and decommissioning.

Platform Orchestrators are a further subcategory of firms producing very systemic components (such as control systems) that allow firms to control the appropriation of value in complex products. Such firms develop proprietary platforms that that enable more effective integration of components through relatively standardised interfaces.

Integrated Solutions While System Integrators are typically manufacturing firms (i.e. Brusoni et al 2001), Davies et al (2007:188) have highlighted a category of firms that assemble systems without an in-house manufacturing capability, for example, BT, EDS, LogicaCMG, and Atkins. This suggests that the traditional systems-seller architecture is being complemented (more uncertainly possibly displaced) by a model in which customers can have systems configured from components from a variety of suppliers as a service (ibid).

2.5 Patterns of Innovation in Services

These systems play a particularly important role in the service sector where improvements in process technology, particularly software enhanced control, influence product innovation (Barras, 1990, Davies 1996, Nightingale et al 2003; Uplanachan 2003; Tidd and Hull 2005). The original taxonomy paper used manufacturing data and consequently said little about services. Professional, financial and business services were positioned within the supplier dominated category, with some retailing and finance moving into the scale intensive category (see Pavitt, 1984:356 foot-note 15 where changes are linked to larger markets and better capital goods; see also pg. 451; 1990). As such, most service firms were conceptualised as being small, having little R&D, limited technical capabilities and adopting non-technical forms of appropriation, such as branding, advertising or knowledge intensity.

Since Pavitt's paper a considerable body of research on service innovation has developed and the old myths that services are an unproductive 'third sector', or have low productivity or capital intensity or skill levels have been debunked (Gallouj, 2001; Miles, 2005; Tidd et al 2003). While measurement lags behind manufacturing (Smith, 2004; Miles, 2005), there is now a recognition that there is something to measure.

Research has traditionally defined services in contrast to manufactured goods (see review by Gallouj, 2001; Miles, 2005). Manufactured goods are seen as material, permanent, produced by people and/or machines, and generally used after purchase. Services, by contrast, are immaterial, semi-permanent, produced by people and consumed as they are produced (Gershuny, 1984:56). In part this reflects goods being things at the time of consumption, while services are states, activities or sensations (ibid).

Miles (1993) for example, categorises services in functional terms into those that (i) effect physical transformations, (ii) 'those directly concerned with changing the (biological or psychological) state of human beings'; and (iii) 'those whose main activities involve information' (ibid., p. 158f). While Miles and Tomlinson (2000:181) suggest that "approaches to clustering developed for manufacturing are unlikely to be reproduced for services" because of lack of data, and service heterogeneity. They instead follow Singelmann (1979) and divide services into (i) producer services, (ii) distributive services, (iii) personal services, and (iv) social services. They suggest focusing on "useful measures for distinguishing between services ... especially, those relating to the knowledge-intensity of their activities, as indicated by such variables as skill composition and investment in development and technological knowledge, and the use of IT and IT services." (ibid).

However, an important study of service innovation was undertaken by Soete and Miozzo (1990) found similar patterns the ones found by Pavitt in the manufacturing sector. They produce a taxonomy divided into: *Networked Services* which includes *large scale physical networks*, found in transport, distribution and wholesale trade and *information networks*, found in finance and communications. These firms are large and adopt cost reduction strategies and appropriate value through scale effects associated with networks; *Specialised suppliers* and science based firms, such as software and knowledge intensive business services; and *Supplier dominated* which covers repairs, cleaning, catering, retail and hotels, and also public and social services like education, health and administration. Such firms tend to be small and rely on non-technological forms of appropriation.[1]

2.6 Services and the Dual Nature of Technology

These similarities to the Pavitt taxonomy suggest that the distinctions between manufacturing and services might be irrelevant or even misleading when understanding patterns of technical change. This is supported by research on the dual nature of technology (Searle, 1995; Nightingale, 1998; Wybo, 1998) that highlights how technologies are composed of both intrinsic physics and a non-intrinsic, imposed function. This distinction suggests the material-immaterial distinction within the service innovation literature confuses a distinction between products and services with a distinction between technological artefacts (which are material) and the functions that technologies can perform (which are immaterial). It then mistakenly assigns each exclusively to manufacturing or services respectively (note the jump from products to manufacturing).

In reality, technological artefacts and their functions can rarely be separated and are found in both manufacturing and services. Putting aside immaterial products like software, there are numerous cases where clear cut distinctions break down. In the UK, for example, the difference between owning and leasing a car long-term is only a tick in a box, reflecting the legal basis of ownership of a depreciating asset rather than any material distinction. Similarly with a range of technologies from oil rigs to software.

The permanent-semi-permanent distinction in which services are consumed as they are produced while manufactured goods are used at a later date can also be misleading as many manufactured products are consumed in the production of other goods and services, while many services can outlive manufactured goods, for example, product warranties and firm incorporations. Tim Brady has highlighted for example, that it would be unfortunate for life insurance to be consumed at the moment it is produced.

Given these problems with oppositional distinctions between manufacturing and services, this paper uses an integrated approach in which manufactured goods are purchased to provide a function while services are purchased to perform a function (Nightingale and Poll, 2000b). In both cases creating a function will require knowledge and technology but in the first manufacturing-case the customer has the knowledge and the legal ownership of the technology, while in the second it is retained by the supplier. Both goods and services generate functions that satisfy needs and many, though not all, needs can be satisfied by either. As Gershuny (1984:56) notes 'services are distinct

[1] Further support for the Pavitt taxonomy in services was provided by Evangelista (2000; Evangalista and Sarvona, 2000; see also Cesaratoo and Mangano 1993) who classified innovation in services into *Technology users* (similar to supplier dominated), *Science & technology based* that are "located very upstream in the knowledge-generating chain" (ibid., p. 212) and provide technical services to Pavitt's science intensive category; *Interactive- and IT-based* software intensive services, which involve close interaction with users (similar to specialised supplier), and *Technical consultancy* which overlaps with science and interactive. Similarly, Tether et al (2001) explored the standardisation of services using German survey data and again found patterns of innovation generally supportive of the taxonomy.

from goods only as alternative means, alternative social arrangements for meeting ends' suggesting that changing technology and social arrangements has the potential to change the relative choice between one or the other.

This choice we suggest is largely, but probably not exclusively, economic in character and reflects the relative cost and performance of having a function generated by technological artefacts that one legally owns. This, in turn, will relate to the quality of the technology, its price, its utilisation over time, and the extent of the knowledge required to operate it satisfactorily. Given both services and manufacturing involve people and technological artefacts, it does not seem unreasonable to consider that their patterns of innovation might be very closely connected. Or to put it another way, after-the-fact legal ownership structures do not seem obvious candidates to influence patterns of innovation. It is more useful to consider services and manufacturing as inter-twined and services involving activities that are removed from, but often important to, the production of material technologies, as when a security guard or accountant works in a factory (Gershunny, 1984). If such activities were outsourced, then the employees would work in service firms, but their day to day activities, functions and interactions with technology would be unlikely to change substantially.

Seeing services as non-innovative or non-technological consequently involves a fallacy of composition that fails to recognise that many essential steps in manufacturing do not involve producing anything, while many steps in the production of services involve technology (Gershunny 1986). This suggests, for example, the emergence of scientific, technical and IT based services simply reflects an increasing division of labour in science and IT intensive production. Similarly, some steps in service provision involves building and operating very sophisticated technology. Nightingale and Poll (2000) for example explore how one financial institution was spending $1bn a year on a technical system. The outsourcing of the production of these systems to Systems Integrator firms, and the further outsourcing of production in systems integration by Integrated Solution providers highlights how changes in the division of labour can drive new patterns of innovation and create new manufacturing tasks *within* services. A point explored in the next section.

This brief review suggests that the number of categories that firms may be positioned within has now substantially expanded. In addition to the original four-fold taxonomy, we now have added e) multi-technology firms, f) information intensive, c) systems integrators, d) networked service firms, e) integrated solutions providers, f) customised mass production firms, g) platform orchestrators, h) technological services, i) interactive client services, j) Science and Technology services, k) virtual services, j) professional services, and many more besides. This expansion raises the obvious concern that the expansion of the taxonomy has come with a loss of explanatory power. The literature now shows considerable evidence of variety, but is substantially weaker on why variety exists, changes or relates to factors that differentiate success from failure (Souitaris 2002:894).

This next section will attempt to explain this variety and the emergence of new categories of innovating firms. Moreover, it will seek to explain the *Sources of Innovation,* for example suppliers in agriculture, users in instruments and basic research in pharmaceuticals. As well as the *Location of In-House Competencies,* for example, R&D labs in chemicals, production engineering departments in automobiles, and IT Systems departments in banks; the *Direction of Innovation,* for example, mainly product in drugs, mainly process in steel, and both in automobiles; and its relationship to *User Requirements,* for example, price sensitive in bulk materials and performance sensitive in pharmaceuticals. Lastly, but less clearly, we hope to explain along Chandlerian lines something about the changing *Size Distribution of Innovating Firms* that tend to be large in chemicals, vehicles, materials processing, aircraft and electronics, but smaller in machinery, instruments, and some software, and about the changing *relationship between products and services,* for example, why personal services have drastically declined, while professional services have expanded, and why systems integrators provide more services than specialist suppliers.

Section 3: Explaining the diversity: towards a typology and a theory

The explanation integrates the two bodies of theory that informed Pavitt's original work: the literature on technological capabilities and the literature on how changes to the effective utilisation of specialised resources of knowledge, tasks, people, organisations and technology create new divisions of labour. The first explains the emergence of diversity while the second explains its evolution. Both interact because the cumulative nature of technical change is increasing the amount of knowledge needed to move new innovations from their initial conception to widespread use. This makes innovation more knowledge intensive, complex, costly & interconnected (Patel & Pavitt, 1998, 2001). Similarly, changes in technology influence the costs and utilisation rates that make new organisational divisions of labour viable (Lazonick, 1991; Pavitt, 1998).

Innovation is a knowledge intensive process that involves creating artificial functions (Tidd et al 1997). The complexity of artefacts; their interactions with a changing environment; and the unpredictable behaviour of starting materials make working out the effects of most modifications analytically intractable (Pavitt, 1987; 1999; Nightingale, 2004). This limited predictability makes theory a poor guide to practice and is why roughly 2/3rds of R&D is development. Consequently, the design, development, and production of useful artefacts involves learning, experimentation, testing, and numerous modification and feed-back loops (Tidd et al, 1997).

This experimentation generates inherently tacit, context-specific, local knowledge (Vincenti, 1990; Constant 1984) that often has limited connection to scientific theorising: it is after all possible to know how to produce an effect without knowing how an effect is produced (Nightingale, 2004). Despite its local nature, such knowledge is important because a purely a-theoretical, empirical approach can make innovation extremely expensive and time consuming. As a consequence, experimentation is guided by knowledge and rules of thumb that are specific to local situations and technological configurations (Vincenti, 1990). Experimentation typically involve creating simplified (i.e. artificially predictable) conditions where the assumptions underpinning these local explanations are true. This allows explanations that are too simple to work in the real world to be used to guide the innovation process. As knowledge is accumulated the simplifying conditions can be relaxed and the innovation process can proceed from 'laboratory conditions' to models, prototypes, field tests and eventually real world applications. This guidance (hopefully) reduces the number of experimental dead ends and generates economies of scale, scope and speed within the innovation process (Nightingale, 2000, 2004; Chandler, 2006).

Such knowledge is organisational and technological, not just cognitive, as firms have to learn across functional boundaries to take advantage of specialised and differentiated technological and organisational knowledge (Pavitt, 1999; Tidd et al 2001). Such knowledge is specific to firms and technologies, difficult to transfer and accumulate (Nightingale, 2004) and differentiated, cumulative and path dependent (Pavitt, 1987; 1999:x). Technological capabilities are therefore firm-specific, causing firms to differ in the efficiency of their production systems and the quality of their product and service innovations (Nelson, 1991). However, while this explains diversity generally, it does not explain why *particular* patterns of innovation and particular types of organisations emerged. To explain this requires exploring how the division of labour (interacting with technology) selects particular forms based on the relative utilisation of resources (Lazonick, 1991).

3.1 Divisions of Labour

Specialisation produces productivity improvements through improvements in dexterity, time saving, the use of machinery (Hutcheson 1755; Smith, 1776:11-13) and managerial co-ordination (Babbage pp. 175-6). Managerial co-ordination is particularly important because:

> "… the master manufacturer, by dividing the work to … into different processes, each requiring different degrees of skill or force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided."

The division of labour is constrained by the relative costs and benefits of specialising resources with the costs typically caused by irreversibility (and therefore inter-dependence) (Maynard-Smith, 1995), and the benefits typically dependent on the extent that specialised resources are utilised (Lazonick, 1991; Chandler, 1977). For Smith utilisation is simply determined by the extent of the market for services, with expanding markets simply increasing the specialisation of tasks and organisations. For Babbage, however, there is also an opposing tendency towards organisational integration as managers can sometimes co-ordinate the utilisation of specialised resources better than markets. For example, as Chandler (1977) noted, expanding markets changed the potential utilisation of scale-intensive production equipment, which was more effectively co-ordinated by managers in large firms (see Hughes 1986 and Nightingale et al 2003 on Large Technical Systems).

When expanding markets increase relative utilisation, points are reached where the benefits of dividing tasks up and giving them to specialised agents outweighs the disadvantages. Like an unpacking Russian doll, this opens up production to reveal technologies and then opens up technologies to reveal specialised knowledge. Thus for Smith as society progresses (i.e. as markets expand) new patterns of technical change emerge (Young, 1928) and improvements in machinery, that were initially the part of the job of *all* users become tasks for *many* specialised makers of machines and eventually *some* "philosophers or men of speculation", or what we would call scientists (Smith, 1776: 16 in the passage that starts this paper). In each case, the tasks differentiate externally in the order of the size of their markets, and internally on their relative utilisation.

This process structurally connects process and product innovations through time. History shows that technologies typically emerge in a very primitive form as new *processes* for producing existing products, typically with narrow technological and sectoral applications and large (and often increasing) development costs (von Tunzelmann, 1993:5). Only after long periods of incremental change is the technology mature enough, the market large enough, and the complementary technical and organisational innovations in place to allow it to be broadly applied as *products* in new areas of application (ibid, 1995). This expands the market and allows further divisions of labour, and associated patterns of innovation to emerge. The long time periods involved (40-60 years) link Freeman's (1982) long waves in pairs, with the process innovations in the first and third (machinery and heavy engineering), linking to the product innovations in the second and fourth (machine tools & railways, and mass production goods) (von Tunzelmann, 2000). This marks the 20th century shift in production technology *from machines to systems*.

Technology therefore has a major influence on the division of labour by structuring a) what tasks exist to be divided up and b) their relative internal and external utilisation rates. This creates structural constrains on what patterns of innovation can emerge and in what order: for example, the substantially smaller market for capital goods compared to consumer goods means much larger markets are needed to induce a comparable division of labour, with the result that a specialised supplier sector emerged later (Rosenberg, 1963). Similarly, systems (made of capital goods) are more costly and complex than capital goods on their own, so that more technological capabilities are needed and markets are riskier and smaller. As a result, specialised producers of systems emerge later still.

Applying Smith's model of a shift from *all* users to *many* suppliers to *some* scientists first to production based around machinery, *and then* to production based around systems generates distinct patterns of internal and external technical change. As the next section shows, the first application generates the core Pavitt taxonomy, while the second allows it to incorporate the new patterns of innovation based around external systems and systems-services production found in the literature.

3.2 Towards a Core Typology

The core Pavitt taxonomy includes supplier dominated (SD), specialised supplier (SS), scale intensive (Sc) and science intensive (Sci) firms that emerged in two steps linking process and product innovation in roughly that order. The first step in the late 19th century involves the differentiation of a specialised supplier (SS) sector providing machinery. This new division of labour followed a process of technological convergence where distinct downstream product markets increasingly shared the same upstream technological inputs (i.e. the same machine tools were used to produce sewing machines *and* bicycles). This substantially expanded the market for capital goods and provided opportunities for in-house machine builders in sectors like textiles to sell enough externally to become viable as distinct organisations (Rosenberg, 1963:423).

This had a number of implications: first, it consolidated supplier dominated (SD) firms for whom it is economically preferable to buy process technology from suppliers rather than invest in the costly and poorly utilised resources required to make machinery in house. Second, improved production technology reduced the cost and improved the quality of consumer goods and allowed consumers to buy technology to produce personal services at home (Gershunny, 1984). This produced a radical decline in the importance of personal services in the economy. Third it set the scene for the emergence of science and scale intensive forms of production by improving the quality of machinery and making production more predictable.

This second step in the late 19th and early 20th century involved the integration of machinery to produce production systems which allowed some firms to generate economies of scale and scope. Such firms needed to ensure high utilisation rates that spread their higher fixed-costs associated with capital intensive production systems (Chandler, 1990). This required high-quality machinery components from suppliers and in-house technological capabilities in production engineering, management and logistics. The resulting improvements in production and distribution further increased market sizes and (with improved instrumentation) made investing in specialised R&D more cost effective.

The emergence of specialised science intensive sector was influenced by the complexity of the knowledge (Rosenberg, 1974). Dividing complex production processes into specialised tasks may simplify them to the point that they can be understood scientifically (in terms of mechanics and mechanical engineering), but biological and chemical processes are too complex for the process to be extended. Technology, rather than the division of labour, was used to simplify chemical processes until they matched scientific theory. Improvements in chemistry, engineering and metallurgy improved purity and therefore predictability (Freeman 1982) and created the conditions where theoretical knowledge from chemistry could be both generated and applied. Improvements in instrumentalities (de Solla Price 1968) produced by specialised suppliers similarly allowed the later economic exploitation of biology and solid state physics (Pavitt, 1996; Rosenberg 1991). In both instances, scientific knowledge initially applied in a narrow range of sectors and technologies to improve *process* technology, gradually improved and accumulated the complementary innovations that allowed it to be more widely applied as *products*.

The interaction between science and engineering therefore involves the application of increasingly complex operational principles to produce technological systems, that create the artificially purified conditions where science can be applied. Examples might include the generation of 'clean rooms' in chip fabrication plants allowing surface chemistry to be applied, or more mundanely, the innovation of the pill allowing a standardized dose of a pharmaceutical to be given to patients. Technical change consequently involves both the recombination and optimisation of operational principles and local, technological specific knowledge to create complexity, and within those systems the creation of atypical purified conditions where complexity is reduced and more universal scientific knowledge can be applied. This creates two distinct, but structurally related technological trajectories and is why science intensive firms draw on 'universal' public science, while specialist suppliers, (and production engineering departments in science intensive firms) draw on local knowledge specific to their customers' and own technological systems. For example, both the chemical and biotechnology product heuristics in the pharmaceuticals industry emerged from process technology used to purify natural products (i.e. morphine from opium; rDNA technology rather than large scale extraction from (infected) animal organs) (Hopkins et al 2006; Nightingale and Mahdi, 2000). The purified nature of scientific products compared to the complex nature of design-based products also makes them more amenable to scale production and more protectable by patents because a) universal knowledge is easier to define and b) apply broadly and c) local knowledge can be more easily innovated around.

3.1 The Core Typology

This differentiation between patterns of technical change in *process* and *product* technologies, with an additional differentiation within product technologies between trajectories related to science and design makes it possible to divide firms along two axes. Differentiating between standard products and innovative products, and between standard production processes and innovative production processes produces a four fold typology. This can be seen in the 2x2 matrix of figure 1, where A represents firms producing standard products with standard process technology, B represents firms producing standard products with innovative process technology, C represents firms producing innovative products with standard process technology and D represents firms that are innovative in both their products and processes.

Figure 1:

Innovative Products	C	D
Standard Products	A	B
	Standard Process	Innovative Process

These firms can be mapped onto the core of the Pavitt taxonomy. Firms in category A are unable to innovate in either product or processes and consequently produce standardised products using standard process technology that they do not innovate themselves. They exhibit the characteristics of the supplier dominated category (SD) and technical change mainly involves technology transfer from suppliers with a limited amount of user modification.

Firms in category B do not innovate in products, but use innovative process technologies. Examples would be found in the scale intensive category of Freeman's (1979) taxonomy, in basic materials, such as metals, glass and paper where innovation is directed towards cost reduction through factor-saving. We would expect such firms to have in-house technological capabilities in production engineering to operate and improve innovative production systems effectively and intelligently source technology from suppliers. These firms exhibit the characteristics of the Scale intensive category (Sc)

Firms in category C produce innovative products with standard processes. Since firms have incentives to improve processes to reduce costs, such firms tend to be in areas of the economy where the opportunities to produce at scale are constrained. This is the case, for example, in the machinery and instrumentation firms that provide the bespoke components for the specialised production systems in category B. The limited production runs make scale production difficult. Because such firms are producing components that address specific sub-functions defined by the larger system, firms need to work closely with users. Such firms take their product ideas from customers and provide technology for a wide range of firms throughout the economy. As such, they exhibit the characteristics of the Specialised Supplier category (SS).

Finally, firms in category D produce innovative products and also use innovative production processes. They differ from category C in being able to produce at scale, suggesting a different technological trajectory (Nelson and Winter, 1982). Science related innovations often have these characteristics because their products can have broader application than a particular subcomponent of a specialised system, and because their purified nature makes production at scale easier. Product innovation involves in-house research that draws on government funded public science, while process innovation draws on suppliers and production engineering departments (cf Sc). Such firms approximate Pavitt's Science intensive category.

These four categories are illustrated in figure 2 where the key characteristics of each category can then be connected. In particular, the *demands of users* is closely connected to the main *direction of innovation*, which in turn is closely connected to the *sources of technology* and the *location of in house capabilities* (Pavitt, 1984; Nelson and Winter, 1982). When users are concerned about the *performance* of the products and services they buy, technical change is typically focused on *product* innovation. Similarly, when users are concerned about *price*, technical change is typically focused on price reducing *process* innovations. Innovative process technology typically comes from external suppliers and in-house production engineering departments. While innovative product technology typically comes from either internal R&D labs and public science (in science intensive firms), or from customers and in-house design offices (in specialised suppliers) (see figure 2).

Figure 2:

Nature Firm	Standard Process	Innovative Process	Product Innovation Characteristics	
Innovative Products	SS	Sci	Performance Product	
			Design and users Design Offices	Internal R&D and public science R&D labs
Standard Products	SD	Sc	NA	
Process Innovation Characteristics	NA Limited Suppliers Limited	Price Process Production Eng & Suppliers Production Eng	Customer Preference Main Direction of Innovation Source Product or Process Technology Location in-house capabilities	
Appropriation Strategy and Size Firm	Reputation (SS) and Limited (SD) Small	IPR, scale and secrecy (Sci) Scale, barriers to entry (Sc) Large		

This 2x2 typology is suggestive in three main ways. First, it indicates that associating innovation with either R&D or patenting is likely to be misleading as they cover only part of the typology and overlook the importance of incremental process innovation and the diffusion of existing technology from suppliers. Secondly, it provides a useful first step when formulating technology strategy by providing a simple framework for understanding technological characteristics at the firm level based only on limited information about customers' preferences and technological trajectory. For example, if customer demand is focused on "price" then innovation will be biased towards process innovations that are either developed internally or sourced from suppliers (depending on the technical opportunities and appropriation set). Such firms will fall within the *Scale Intensive* category and the main focus of technology strategy will be developing cost saving process improvements within production engineering departments and sourcing key technology from suppliers. Scale economies provide a means of appropriating returns so we would expect firms to be large, but also vulnerable to price wars. If the capabilities or appropriation opportunities are lacking the firm will fit with the Supplier Dominated category and should focus on sourcing technology from suppliers and finding new alternative sources of innovation to avoid price competition.

On the other hand, if customers are demanding "performance" then the focus of innovation will be on improving products or services, which implies a bias towards product innovations. The main trajectories of product innovation are science intensive and design intensive trajectories associated with science and specialised supplier categories respectively. For the first of these internal R&D and access to public science are key sources of new products. Technology strategy should focus on building capabilities within R&D to draw on external knowledge and develop research into useable products. Appropriating the returns to innovation typically through the use of complementary assets such as IPR is also a key focus. For Specialised Supplier firms that produce design-intensive components, subsystems, or systems, innovation typically comes from interacting with clients to provide systems and solutions designed to match their particular requirements. The focus of technology strategy should be on building up capabilities within design offices, interacting with customers and working to exploit capabilities as widely as possible. Where customers want both performance and price, firms must combine both sets of capabilities and generate both product and process innovations. This is typically the case in science intensive sectors where firms must combine R&D focused product innovation, with scale-intensive production-engineering led process innovation.

Thirdly, the 2x2 typology can be used to reinterpret the changing patterns of innovation picked up in the literature in the light of the structural constraints discussed previously. Thus Rosenberg (1963), Chandler's (1977) and Scranton (1984) focus on segments of the typology differentiating in the 19th century (see figure 3). Freeman's (1979) three-fold taxonomy and Pavitt's four-fold reflect innovation in the UK in the 1970s. The extensions to the taxonomy, such as Pavitt's hidden category related to complex infrastructure and information intensive services and Archibugi's (2001) multi-technology firms reflects further changes in the division of labour, related to systems, that we address in the next section.

Figure 3 about here

3.1 Towards a Dynamic Typology

The core typology is not static and emerged from ongoing changes in the division of labour. The addition of new categories is simply the result of this process being continued but applied to complex production systems rather than machinery (i.e. from *all* systems users, then *some* systems integrators, and then a *few* solution providers).

System based Production

In the third step, the size of the market for complex technological systems increases, allowing specialised systems-integrators to improve the utilisation of their specialised assets and become increasingly viable as distinct organisational forms. As might be expected, this process has many similarities to the specialisation of machine tool makers in the 19th century. The initial expansion of the market occurred through a convergence between state and commercial market following the privatisation of many state-controlled utilities since the 1970s. Firms sell business-to-business, work closely with their customers, use craft based, batch production processes to produce customised products. Similarly, at the industry level technological capabilities move upstream from the old vertically-integrated, national monopolies (e.g. NTT, ATT, BT) to systems integrators (i.e. Ericsson) making the categories more visible (Davies, 1996).

There are however several differences related to the smaller markets, larger costs, higher prices and higher technological complexity of these systems compared to traditional machinery (Hobday, 1998, 2000; Rush, Bessant and Hobday, 2001). As already noted, organisational specialisation in their production happened later because markets are smaller. Secondly, production and design involve more hierarchical decomposition of products, outsourcing and project management. And thirdly, the boundary between manufacturing and services is shifted more towards services. These differences are, as might be expected, driven by relative utilisation of new divisions of labour.

As such, SI is a form of industrial organisation that balances the risks and rewards of the division of labour, that differ as one moves from high-level architectural design down to the (mass) production of standardized components. High level design and production is kept in-house because of the low production volumes, and systemic inter-connections between components that make design and production fragile and risky. While outsourcing production to webs of suppliers enables them to achieve higher utilisation rates by selling to multiple customers, and enables systems integrators to access technology from a wider variety of sources. During the actual production process, hierarchical project based production allows resources to be temporarily reconfigured and reused in flexible ways improving the management of the higher risks involved. This is not just a simple Smith-Simon modularisation process for two reasons. First, the components, design and configuration are not fixed at the start of the process, and secondly, because firms need to develop develop new generations of future technology (Prencipe, 1998).

These advantages can be improved through the use of proprietary platforms with standardized interfaces that encourage production economies. Robust (software) platform technologies help reduce the higher risks of production associated with systemic products because they allow easier integration of components and improved systems performance. Platform orchestration firms (PO) focus on these technologies and can achieve substantial appropriation of value. However, they need to ensure a sufficient mass of suppliers will adopt their standards, often leading to highly competitive standards-clashes. This ability to appropriate value, and the very large barriers to entry associated with the knowledge intensive nature of PO firms, means that such capabilities are closely guarded. Even in consumer sectors such as mobile phone handsets, companies like Nokia retain software platforms for the higher complexity multi-media and internet enabled handsets, while licensing previously proprietary high-speed WCDMA/HSDPA technology to first tier suppliers. So while such firms may outsource large amounts of production, and configure standardized components to generate scale economies in production, they do not outsource the embedded software and platforms that are key to reducing the risks of production and appropriating rents from future generations of technology.

Boundary between Products and Services

The shift towards systems also changes the relative balance between products and services in three distinct ways. First, as already noted, by radically reducing the costs of producing consumer products, it allows consumers to buy technology and produce services at home (Gershunny, 1984). People now buy cars, washing machines and vacuum cleaners rather than employ drivers, laundries and cleaners, even though the utilisation rates of those technologies are often very low.

Secondly, by increasing the extent and complexity of production it has increased the importance of service elements within production, which in turn has encouraged the expansion of professional service firms (Gershunny, 1984). These Professional Services (PS) have emerged as a distinct trajectory based around up building specific, typically high-value, knowledge. The knowledge intensity of professional services, the barriers to entry associated with legal accreditation, and the low utilisation rates that most customers will experience make such firms particularly viable as specialised entities. They can be found in design (PS-D), science and technology (PS-T), finance, medicine, law and accountancy (PS-I). While the provision of these services does not involve the economic transfer of technology, the actual services themselves are often very technology intensive. This can be because technology is a key input to the service (i.e. materials testing services or medicine) or because process technology is used to generate scale and scope economies through the provision of standardised or easily modifiable services (see, Tether, et al 2004).[2] As a consequence, service firms can be supplier dominated and draw on machinery from specialised suppliers, or they can build complex technological systems themselves (i.e. networked services (N)) or they can rely on systems from solutions providers, which they either operate themselves, or have operated as a service by solutions providers, or they can adopt a virtual model and outsource everything (VS).

Thirdly, the higher fixed costs of infrastructure, the higher life-cycle costs of systems that might operate for decades, and the deeper operational knowledge needed with more complex systems, and its role in driving innovation, together increase the relative size of the market for specialised technical and operational services. The higher fixed costs of production means that a service based division of labour, in which the technology is owned by the service provider not the customer, generates better capacity utilisation and therefore more ability to spread high fixed-costs. For example, virtual firms (VS) in capital intensive sectors like telecommunications buy spare capacity from network owners and provide marketing-lead services, such as virtual private networks, on infrastructure provided for, owned and operated by other firms.

Similarly, the specificity, complexity and value of operational knowledge as a source of future innovation (Nightingale et al 2003) make the provision of complete operational packages of services to customers more attractive. As Davies et al (2007:183) show many system suppliers are increasingly focusing on service provision and offering not only to design and integrate components into a system, but also operate, maintain, finance and decommission the system over its life cycle (see also Galbraith, 2002; and Nightingale 1997 on the emergence of 'power by the hour' services in the aero-engine industry). The resulting stream of revenue from such integrated solutions (IS) business models has the advantage of enabling firms to tap the large lifecycle operational costs (that often substantially exceed the highly volatile profits from project based production) (Davies et al 2001).[3]

As with systems integration, integrated solutions represents organisational responses to changing divisions of labour. In this case firms integrate forward into the provision of services to extract rents and exploit scale and scope economies through the reuse of processes and project related knowledge and technology (Davies et al 2007:185).[4]

Fitting into the Taxonomy

Fitting these new patterns of innovation into the existing typology requires a few modifications as their low volume but often very innovative production processes suggest the previous association of innovative processes with scale-intensive production is misleading. Woodward's (1966) classic analysis of industrial organisation highlights how

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[2] When a) utilisation rates go up, b) knowledge requirements go down, or c) the costs of technology change customers will potentially buy technology and produce professional services at home. Kits for measuring blood pressure, that were previously only sold to doctors are now wide-spread, and the software programmes that accountants use have been simplified and sold to customers to complete their tax returns.

[3] As early as the 1900s the provision of electrical systems involved using 'Trained engineers … to market, install, and service the new machines, for faulty installation could result in death by electrocution or fire. … engineers almost always knew more about the safe and efficient use of the new power machinery than did their customers. In addition, because of the higher cost of the equipment, these companies often found that they had to extend greater amounts of credit to industrial buyers than did the producers of lighter machinery' (Chandler, 1990:68).

[4] Solutions providers also provide strategic advice and help customers design and implement new business models or expansions into new markets with important strategic implications (Flowers, 2007). This is generating convergence between traditional engineering led solutions providers, IT consultancies, and financial institutions (investment banks and even private equity houses).

craft, batch and flow-mass production can all be innovative (Hobday, 1998) and this is used in figure 7 to show how the CoPS related categories of CoPS, Systems Integrators, Integrated Systems providers and Platform orchestrators fit in relation to the original Pavitt taxonomy.

Figure 9:

Nature Firm		Standard Process	Innovative Process (Flow)	Innovative Process (Project)	Product Innovation Characteristics
Innovative Products	Trajectory				Performance Product
	Systems		Sc PO IS	SI (SI-PO) CoPS IS	Design (including software), users, suppliers, intelligent customers regulators Design offices, software testing services, project managers able co-ordinate webs of suppliers
	Information	PS	MTF-I		Learning Skilled professionals
	Science	PS-S&T	MTF-Sci		R&D, public science R&D labs
	Design	PS-D, SS	MTF-D		Design offices, users/customers Design offices
Standard Products		SD, V-S	Sc, N-S		NA
	Process Innovation Characteristics	NA Limited	Price Process	Price Project	Customer Preference Main Direction of Innovation
		Suppliers Limited	Production Eng & Suppliers Production Eng	Project managers PM offices	Source Product or Process Technology Location in-house capabilities
	Appropriation Strategy and	Non-tech: reputation, marketing (V-S), links to customers (PS, SS). Limited (SD), Design (SS)	IPR, scale and secrecy (Sci) Scale, barriers to entry (Sc)	Reputation, project management (SI) Technology and close links to customers (CoPS)	
	Size Firm	Small	Large	Large SI, Medium CoPS	

4. Exploring the explanation: the MINE dataset

The categories within the typology are not intended to be fixed, and only represent particular classes of innovative activity along particular technological trajectories at particular points in time. While the core taxonomy covers a large proportion of innovative activity, and the updated version incorporates changes in the economy related to the development of systems and their influence on service provision, by its inherent nature the taxonomy will not be perfect. Any theoretical structured inductively derived and deductively generated from first principles is likely to be good at some things, and stink at others. Hence, in this section we explore its strengths and weaknesses using data from a large and very detailed survey of 950 international firms developed as part of the MINE project (Miller et al 2006).

This data set has an advantage over data sets such as CIS in that it is not based on questions that assume the Pavitt taxonomy is true. It is also much more detailed than CIS and unlike CIS we can be sure it was filled in by VP of R&D or CTOs. As with the original SPRU data-set the data has the advantage of being very rich, but the disadvantage of a direct sampling method. While the large size of the sample may reduce this problem some what, the data is not representative. In particular, Supplier Dominated firms are probably self-excluded, small firms will be under-represented, as will professional service firms. Service firms are particularly under-represented.

INSERT TABLES 1 and 2 here

The clustering was then use to produce a taxonomy based on the ways value is created and captured across two contextual dimensions of product architecture (stand-alone; closed integrated systems; and open modular systems) and market evolution (market creation and market maintenance). This produced a six-fold deductive taxonomy of:

Patent-driven discovery involves 'technology races' based on frontier knowledge production, expertise and ability to work with government or industry regulations. Firms in this category rely on recruiting high quality scientists and entrepreneurs and balancing their portfolio of internal and external research projects. Innovation is largely in-house, with approximately 60% of relevant ideas emerging internally. The average expenditure on R&D is 16.5% of sales, with an additional 5.45% to build capabilities for strategy making, marketing and production. The industrial ecosystem is typically composed of a few large competitors surrounded by many smaller specialized complementary firms. The products being produced are largely self contained and customers have clear understanding of their performance. Customers' main concern is performance and clarity about the performance of products typically involves regulatory approval. Appropriation of revenues is done through IPR and regulatory approval with the result that firms are typically large and focus on building and managing a stream of products within their portfolio to maintain income streams as older products lost patent protection. Typical sectors in which such firms would be found include pharmaceuticals and agribusiness. As such, this is similar to Pavitt's *Science Intensive* (Sci) category.

Cost-based Competition and process optimisation is found in capital-intensive sectors producing commodities such as metals, industrial gases, oil and gas, electrical power, etc. Innovation in this category focuses on efficiency, market share, and scale and scope economies as buyers capture value through low prices and producers seek volume and cost reductions. A key focus of innovation involves finding new applications to renew markets. Market selection is primarily based on price and customers have clear understanding of products. Investments in innovation are, on average, 2.57% for R&D and 1.3% for capabilities building, for a total of 3.87% of sales. The competitive ecosystem within which such firms operate is composed primarily of large producers and networks of suppliers and consultants. Firms often compete only on price and profit margins can rapidly disappear as competition increases. Given the large scale of production investments in innovative capabilities are generally low, at 2.6% of sales on R&D and 1.3% on building other capabilities. This category is similar to Pavitt's *Scale intensive* (Sc) category.

Customized mass production involves a settled platform and a dominant design, in which coherent architectural choices have emerge allowing firms to focus on mass production (often on a global scale) and incremental product innovation to enhance branded products. Firms often rely on robust design practices and modify customer facing components to suit local markets based on design and styling. Customers in this sector typically focus on both price and performance, where customer criteria involves style, price, reputation and brand. Product innovation involves working with buyers to understand how to modify products to match their requirements while maintaining a dominant design. Given the focus on price, process innovation involves exploiting global supply chains and production networks. Given the scale of production most firms are large and many exploit global production networks to gain scale economies in production, core design and engineering. Value in this category is largely captured by assemblers rather than component suppliers. However, suppliers of key components may, in some circumstances, hold considerable market power. Customised mass production represents an evolution from standard mass production in which the advantages of global scale production for core components within a shared portfolio of products are combined with the additional value captured by providing customers with designs that match their particular, often local, concerns about style and performance. This category is similar to the Multi-technology Design (MTF) firms in the taxonomy.

Systems Integration involves generating closed system type products that provide buyers with sophisticated methods and services to manage design activities, coordinate the work of thousands of engineers on a real-time basis and ensure inter-organizational informational flows. These types of firms compete by performing complex tasks such as testing design hypotheses, accelerating product design and enhancing quality better than their competitors, for example in the production of drug-design software systems sold for pharmaceutical firms; design-automation systems for semi-conductor manufacturers; or factory-automation products and services for mass manufacturers. In these types of markets buyers focus on costs, functionalities, and risks and continuously raise the expectations. Innovation is typically based on accumulated engineering expertise and heavily in innovation. 32% of sales go to R&D, accompanied by efforts to build strategy, marketing and production capabilities, for a total of 44.16% of sales.

System Extension and Engineering firms address engineering and implementation of closed systems (e.g., mission-critical I.T. or production systems) in mature markets that involve major capital investments to improve efficiency. For example, investments in large-scale networks for electric power, banking, retailing, financial services, manufacturing, communications, and other sectors where buyers want to radically transform their cost structures, and improve their delivery of new products and services. Such projects often put operators at risk because of the financial commitments, the risks of cost overruns and the performance failures involved. Within these firms innovation focus on collective problem solving involving large buyers and hierarchies of specialized consulting and engineering firms often characterised by significant consultancy. On average, 15.03% of sales are invested in R&D and capabilities building. Knowledge accumulation can involve the formalization of methodologies based on the codification of past experience and reputation and experience are dominant selection criteria.

Platform orchestration involves using high-stakes market-creation strategies to dominate value extraction from products and platforms involving the integration of many components. Network effects typically mean that few platforms will survive and platform orchestrators have to build demand and co-ordinate the activities of many suppliers. Spending on average 10.23% of sales on R&D and capabilities building.

6. Conclusion

Previous taxonomies of patterns of innovation have tended to be static and based on ex-post categorisations of snapshots of data. As a result, they tend to be largely silent on processes of change. The taxonomy developed in this paper is intended not just to classify but also to explain the dynamics of change. Perhaps surprisingly, given repeated claims of revolutionary change that accompany new technology, we have found that a very simple explanation developed from first principles can explain a considerable amount. These first principles are not new and go back to Adam Smith and Babbage. Our only two claims to novelty are to have applied it to first to machinery and then to technological systems, and then to have used it to explore the changing boundaries between manufacturing and services.

By using this first principles explanation to generate a dynamic taxonomy of technical change that shows how distinct categories emerge and are changing the paper makes a number of contributions. First, by showing multiple forms of innovation with very different sources, the paper provides a more useful basis for thinking about technology policy than the current extremely misleading focus on R&D intensity. As the taxonomy shows, R&D is only important as a source of innovation in a small fraction of the economy associated with high tech manufacturing. This is generally less than 3% of the economy and declining as a proportion of employment (Smith, 2000). The analysis therefore makes us extremely sceptical of 'knowledge economy' rhetoric that universities are "the" source of innovation (especially given the very limited importance placed on them by firms within high-tech manufacturing), let alone regional development and large scale economic growth (see Acha et al/NESTA, 2006). This is consistent with the failure of policies related to science parks and university spin-outs, criticisms of the completely unrealistic focus on biotech in current technology policy (Nightingale and Martin, 2004) and criticisms of the current EU focus on networking (Dosi et al 2005). A more useful approach for technology policy would be to pay attention to innovation in the other 97% of the economy and support the diffusion of existing technology, incremental improvements to in-house production technologies and support for other non-R&D based innovation (Mowery and Rosenberg, 1994).

Secondly, and perhaps most importantly given the size of the service sector, the paper makes a contribution by integrating previous work that has tended to see services and manufacturing as distinct. By distinguishing between technological artefacts and the functions they generate, the paper has hopefully shown how manufacturing and services inter-relate, highlighting that service sectors can be extremely technologically sophisticated. This helps explain a major long-term change in the economy in which personal services have declined and highly paid, often very technologically sophisticated professional services have increased as a proportion of the economy (Gershunny, 1984). For Gershunny (1984) this change amounts to a major social revolution, but twenty years after he explained it, it is still poorly appreciated.

Thirdly, the framework can be used to assess the novelty and likely valid application of fashionable new ideas. To illustrate this the section will assess user-centric, open, and disruptive innovation.

User Centric Innovation
Recently there has been increased academic and policy interest in users as drivers of innovation (i.e. Nesta, 2006) with suggestions that information technology is somehow generating a paradigm change with open-source software as its exemplar. The importance of users was well known to Adam Smith (and indeed to Plato's flute makers) and it has been explored in a series of important academic studies (Rothwell et al 1974, 1977; von Hippel 1978, 1988; Gardiner and Rothwell, 1985; Rosenberg, 1982) that clearly differentiated between the important industrial-marketing role of users in clearly articulating their requirements (Rothwell et al 1977) and their role as sources of innovations (Freeman, 1968; Rothwell, 1975; von Hipple 1988).

The taxonomy supports the importance of users. This is a necessary corrective to the over-emphasis on science and R&D as 'the' sources of innovation. However, care must be taken not to make the same mistake as Smookler (1972) and over-estimate the role of users based on over-generalisation from case studies almost universally taken from the Specialised Supplier category. While the taxonomy suggests that users are important within the information and systems trajectories (though to a lesser extent) it suggest that they are not the only source or a new source. They are typically only important within design-intensive trajectories where knowledge is very local and technology specific when customers want performance. Users are not important in the science intensive and rarely in the information trajectories. Where customers are concerned about price, process innovations typically come from internal production engineering department and specialised suppliers. As a consequence, users are largely irrelevant, for example, in the classic basic materials sectors of steel, concrete, clay, glass and grain. However, *some* atypical customers may be concerned about performance and they *might* be sources of innovation. The lack of attention to production suggests a key weakness in the user-centric paradigm, as effective (scale) production is often key to appropriating returns and reducing costs. Moreover, production technology and product technology are rarely distinct (Cardiff, Umplanachan) and the importance of manufacturability (Rothwell and Gardiner, 1986) suggests users-derived changes that impose costs on production can be very damaging.

The taxonomy can also help explain why changes in technology can make users more important. Since users are sources of innovation for specialised suppliers and increases in the division of labour turn internal processes innovation into external product innovations, then all else being equal, users will gradually increase in importance. The same process applies to consumer goods (see for example, Jeppesen and Molin, 2003): as they increase in complexity, operational knowledge becomes more important, and can be utilised to change the artefact to improve the service. As user knowledge goes up, and the relative costs of better performing technology goes down, technological capabilities move downstream and users should increasingly be sources of innovation. This would be dependent on relative utilisation costs, and therefore trajectory specific: i.e., more prominent with computer games and mountain bikes, than with drugs, air-craft and nuclear power stations. Moreover, some changes in technology make users less important – for example the shift from mechanical to software control in automobile engines. In conclusion the taxonomy suggests users are important sources of innovation in certain categories, but not in others, and increased attention to users helps steer policy makers away from an over-emphasis on R&D.

Open Innovation

There has also been increased academic and policy interest in open innovation (Chesbourgh, 2000; AIM, 2004). The key idea behind open innovation is the notion of a shift from an older paradigm in which firms relied on internal R&D laboratories and internal idea generation for innovations, but now, as knowledge is so widely distributed firms need to source their innovations externally. As with users, the importance of external sources of knowledge was well known to Adam Smith, and back in 1962 Enos' study of Dow chemicals found that *all* the top 15 major innovations that Dow had produced had been derived from external sources. Similarly, external sourcing of innovation has been highlighted as a central feature of effective innovation management in a large number of key academic texts (Rothwell et al 1977; Rothwell, 1990; Cohen and Levinthal, 1990; Pavitt, 1990; Rosenberg, 1994; Alfonso 1997).

Using the taxonomy to assess the idea's strengths and weaknesses suggests that the insight behind open innovation - that external ideas are important to innovation and becoming more important would seem to be correct. External sources of innovation and technology are important in all categories of the taxonomy. The taxonomy however, has the additional benefit of being able to articulate *which* external sources will be important for which category – suppliers for process technology; users, webs of component suppliers and regulators for systems integrators; external regulators and professional networks for professional services; public science for science intensive; and users for firms in design based trajectories. The taxonomy can also highlight where an over emphasis on external sources of innovation can be misleading. For example, the localised nature of the knowledge needed to innovate and operate innovative process technology makes it inherently firm specific.

While open innovation is now conceptualised as a universal shift from internal to external, Chesbourgh's original research was much more sophisticated and involved a subtle exploration of the interplay between changing divisions of labour and changing business models. While this link is entirely consistent with the taxonomy's focus on changing categories, the taxonomy fails to properly explore these processes, particularly the potential for conflict between business models as firms differentiate which Chesbourgh's research shows are very important (see also Mitchell, 1992).

The taxonomy is considerably better at explaining the changing patterns of R&D that have often triggered interest in open innovation. R&D should not be equated with innovation, and is only important in a small number of categories, principally within the Science intensive category, and to a lesser extent with innovative scale intensive forms of production. As a consequence, changes in R&D may represent changes in taxonomic category in response to new divisions of labour, rather than a binary shift from internal to open-R&D. For example, with telecoms the opening up of markets in the 1980s, saw changes in the division of labour with technological capabilities moving from vertically integrated national carriers upstream to systems suppliers such as Nokia and Ericsson (Davies, 1996). Competitive pressure was placed on incumbents by new entrants working with more efficient technology who were unencumbered by high-fixed cost legacy infrastructure. Reduced income saw central R&D spending fall. Older telecoms carriers either became supplier dominated or like BT and C&W moved downstream into service provision, where they have been very successful at exploiting the new division of labour. In neither case did they move from closed to open innovation within the same category.

Similarly, with IBM, one of Chesbrough's case studies. IBM originally had full component capabilities in-house but then abandoned the production of most standardized components to new entrants, better able to take on the risks and sometimes limited returns of scale intensive production in highly competitive markets. IBM them exploited its broad base of capabilities and focused on the provision of integrated solutions to transform its business model into a very successful integrated solutions provider (Davies, 2007:184). This change was not a shift from an internal to open model of innovation, but again a shift in taxonomic category. Senior managers successfully took advantage of a ongoing change in the division of labour which created new patterns of innovation and modified the organisational locus of R&D. This is why firms that have not changed categories – for example, R&D intensive firms such as Pfizer and Merck – have not seen a similar collapse in R&D spending. Instead, changes in the division of labour within the category has seen the emergence of a Toyota style knowledge supply chain of biotech firms in the sector in which firms spend up to 25% of their *increasing central R&D budget* externally (Hopkins et al 2006). These taxonomic differences help explain why the empirical evidence on R&D shows open innovation is declining rather than expanding (Patel, 2006). In conclusion, the taxonomy suggests that open innovation is an important phenomenon, but it is just a special case not a universal phenomenon. Talk of a binary shift from closed to open innovation is misleading and over-simplistic, and changes should be understood in terms of shifts in taxonomic category, which Chesbourgh's analysis supports, but adds additional nuance to by highlighting the role of changing business models.

All these new models of innovation serve useful rhetorical functions. Open and user centric innovation resonate with concerns about empowerment, while disruptive innovation provided a focus for managers at the top of the economic cycle for whom everything seemed to be going well. In all three cases the models provide very useful correctives and illuminate key features of technical change. The taxonomy also suggests that they have their weaknesses and care must be taken when extrapolating them from taxonomic categories where they work well to the entire universe of innovative activity.

As the empirical data shows the taxonomy still has a number of substantial weaknesses…..

By adopting a structural emphasis the taxonomy downplays the role of agency, particularly, managerial agency in driving and influencing change. Future work may wish to explore how these structural changes influence the sorts of managerial choices highlighted by Chesbourgh (2000). For example, if one assumes managers wish to 'make money' (Winter, 2006) then the disruption associated with attempting to utilise assets beyond their intended capacity is likely to focus their attention (Rosenberg, 1980) and direct investment. Similarly, under-utilised resources can provide the basis for organisational change and growth (Penrose, 1959, Baden-Fuller 1977) in a way that is consistent with the pattern of change highlighted here (Penrose, 1962). Under-utilised assets are often less obvious to managers as work, like a gas, expands to fill all available space. Nether-the-less, they provide the basis for Penrosian growth, and the exploitation of scope economies highlighted by Chandler (1977). At present, it is not clear what drives particular changes in taxonomic category, nor what the implications are for strategic choices, and new business models. While the new taxonomy on its own cannot answer these questions, it does hopefully provide a basis from which to explore them.

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Table 1: Coefficients

Joute_Épurée	non utlisé	Prod. de masse, monopole	Production de masse	R&D brévets	Conseilt et ingénierie	Intégrateurs	Prod. de masse personnalisée	Bataille d'architecture	Total
Contexte-01-dynamisme [dynamism]	0.19	-0.53	-0.54	0.21	-0.04	0.40	-0.08	0.56	0.00
Contexte-02-science & connaissance [science	-0.02	-0.28	-0.22	0.21	-0.18	0.30	0.02	0.07	-0.01
Contexte-03-interopérabilité [interoperability]	-0.29	-0.42	-0.15	0.15	-0.21	0.25	-0.06	0.43	0.00
Contexte-04-turbulence [turbluance]	0.46	0.07	-0.23	-0.31	-0.15	0.27	-0.07	0.20	-0.01
Contexte-05-interdépendance [inter-depedenc	-0.21	-0.66	-0.12	-0.02	-0.19	0.34	-0.03	0.40	0.00
Contexte-06-rivalité [rivalry]	-0.04	-1.00	0.37	-0.49	-0.28	0.34	0.15	-0.04	0.01
Contexte-07-regulatory approuval	0.29	0.09	-0.10	0.31	-0.20	0.16	0.32	-0.63	0.00
Contexte-08-coût [cost]	-0.03	0.29	0.42	-0.45	-0.53	0.08	0.22	-0.35	0.00
Contexte-09-progression continue mais lente	0.15	0.04	0.14	-0.41	0.09	-0.04	-0.16	0.11	0.00
Contexte-10-stimulation de l'entrée [stimulatic	-0.17	-0.05	-0.07	0.00	-0.15	0.13	0.23	0.01	0.01
Contexte-11-expertise des clients [client expe	-0.03	-0.45	0.13	0.22	-0.05	0.10	-0.15	-0.09	0.00
Création Valeur-1-Intensité de l'innovation [int	0.23	-0.98	-0.21	-0.34	-0.04	0.48	0.13	0.40	0.01
Création Valeur-2-Orchestration des standard	-0.01	-0.46	-0.21	-0.15	-0.28	0.36	-0.03	0.40	-0.02
Création Valeur-3-Optimisation des coûts [cos	-0.20	-0.24	0.45	-0.31	-0.36	0.33	0.36	-0.48	0.00
Création Valeur-4-Productisation de la scienc	0.09	-0.27	-0.35	0.79	-0.19	0.45	0.10	-0.30	0.02
Création Valeur-5-Co-innovation	0.25	-0.48	-0.09	0.19	0.29	0.21	-0.53	0.17	0.01
Strategy-1-Radical initiative	0.16	-0.80	-0.30	0.14	-0.14	0.32	0.08	0.43	0.01
Strategy-2-Organizational Flexibility	0.41	-0.22	-0.14	0.03	0.18	0.16	-0.42	0.14	-0.01
Strategy-3-Natural Resources Ownership	-0.18	0.14	-0.08	0.13	-0.38	0.36	0.22	-0.15	0.01
Strategy-4-IP and technological superiority	-0.11	-0.88	-0.24	0.70	-0.33	0.40	-0.06	0.19	0.00
Strategy-5-Brand and reputation	0.20	-0.44	-0.01	-0.42	0.31	0.24	0.13	-0.09	0.01
Strategy-6-Influence on public reglementation	0.47	0.76	-0.15	-0.14	-0.43	0.37	0.27	-0.62	-0.01
Strategy-7-Scale	0.14	-0.38	0.39	-0.52	-0.39	0.24	0.15	-0.17	0.02
Strategy-8-World scope	-0.52	-0.30	0.07	-0.13	-0.16	0.44	-0.13	0.14	-0.01
Strategy-9-Continuity	-0.07	-0.02	-0.08	0.00	0.07	0.12	-0.11	0.02	-0.02
Strategy-competitive moves-1-Branding	0.04	-0.97	-0.10	-0.56	-0.06	0.38	0.36	0.24	-0.02
Strategy-competitive moves-2-Technological		-0.21	-0.74	-0.37	0.49	-0.29	0.63	-0.14	0.35	0.01
Strategy-competitive moves-3-Regulatory gar	0.38	0.65	-0.21	0.15	-0.40	0.49	0.14	-0.51	0.00
Strategy-competitive moves-4-Scale & acquis	-0.12	-0.32	0.52	-0.63	-0.06	0.30	0.17	-0.36	0.00
Strategy-collaborative moves-1-alliances & lic	-0.16	-0.59	-0.33	0.38	-0.33	0.58	-0.07	0.23	-0.01
Strategy-collaborative moves-2-creating the e	0.26	-0.52	-0.14	-0.37	-0.31	0.51	-0.22	0.55	0.00
Strategy-collaborative moves-3-standardizatic	0.24	0.28	-0.04	-0.27	-0.21	0.56	0.24	-0.57	-0.01
Resultats_Inovativeness	0.07	-0.58	-0.18	0.10	-0.11	0.14	-0.14	0.38	0.00
Resultats_Rentabilité	0.16	0.15	-0.12	-0.12	0.12	0.04	0.01	-0.09	-0.01
Resultats_New_Business	0.17	-0.20	-0.05	-0.05	-0.01	0.26	-0.07	-0.13	-0.01