Services and 'Systems of Innovation'

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Abstract

This paper provides an overview of findings and conceptual arguments with respect to services, and innovation in services, especially from a 'systems of innovation' perspective. We argue that the great diversity of service activities is not reflected in the depth of understanding of innovation in services. The study of services brings to the fore the inter-relationships between business models, organisational forms, technology and outputs. Studies of services also highlight the significance of knowledge forms other than, or complementary to, technological knowledge (and R&D). In particular, the significance of market knowledge and procedural knowledge is highlighted. Many services show high degrees of interaction and interdependency between the service provider and the service user, as well as between provider and equipment suppliers, and there are important connections between service innovation and artefact innovations developed by manufacturers. Such interaction and interdependency is a central feature of all true 'systems of innovation' and, as in manufacturing, the diversity of activities within services means there is certainly no single 'system of innovation'. Instead, we argue there are multiple 'systems', but 'sectors' or 'sub-sectors', as these are conventionally defined, do not bound the systems of innovation. Instead, the systems of innovation often develop around identifiable sequences of problems (or opportunities), such that the problem sequence at the heart of the 'system of innovation' becomes the focusing device around which the system is developed. As the problem (or opportunity) changes, or is redefined, so the system can change, changing the agents involved and the relations between these agents. One important implication of this view is that firms can take a leading role in assembling innovation systems in the pursuit of their own competitive advantage. Innovation systems at this level are to a substantial degree transient; they evolve as the problems of the moment evolve. From this perspective, systems of innovation involve a wide range of agents from many different 'sectors' (often including both manufacturers and service providers). An interesting feature of these systems is that the agents involved (and the inter-relationships between these agents) can change over time, thus the boundaries of the system are not fixed, but are dynamic, and evolve.

Introduction

This paper provides an overview of findings and conceptual arguments with respect to services, and innovation in services, especially from a 'systems of innovation' perspective. It draws especially on the work undertaken on innovation at airports, in health care, and in retailing, but will also be informed by wider considerations of services and their innovation activities. By 'services', we mean all sectors conventionally identified as services, although telecommunications and computer software – which are especially technological - were examined more fully and separately by other contributions to the European Sectoral Systems of Innovation (ESSY) project.

The paper begins, in Section 1, by outlining the economic significance of services and discusses what is meant by services. Section 2 concerns the 'systems of innovation' perspective with regard to services, and summarises the work undertaken on services within the European Sectoral Systems of Innovation (ESSY) project. Section 3 then draws on these studies to provide summary answers to main questions raised by the 'systems of innovation' perspective in relation to services. Finally, Section 4 provides a new perspective on 'systems of innovation' that has evolved out of our work within ESSY.

The main points of the paper are the following:

- Services are not (normally) engaged in the production of tangible products, but cover a huge range of diverse activities, associated with various types of transformation (i.e., physical, spatial and temporal transformations, affecting people, things and information). The great diversity of service activities is not reflected in the depth of understanding of innovation in services, which has been neglected in favour of studies on manufacturing. This said, there are certainly important connections between service innovation and artefact innovations developed by manufacturers. But more research needs to be done before we can claim a comprehensive understanding of the problems of innovation generation and diffusion in relation to services.

- The study of services brings to the fore, to a greater extent than studies of manufacturing, which tend to focus on the product produced and the process of production, the inter-relationships between business models, organisational forms, technology and outputs. Studies of services also highlight the significance of knowledge forms other than, or complementary to, technological knowledge (and R&D). In particular, the significance of market knowledge and procedural knowledge is highlighted.

- Many services show high degrees of interaction and interdependency between the service provider and the service user, as well as between provider and equipment suppliers. Such interaction and interdependency is a central feature of all true 'systems of innovation' and, as in manufacturing, the diversity of activities within services means there is certainly no single 'system of innovation'. Instead, there are multiple 'systems' or patterns. Moreover, 'sectors' or 'sub-sectors', as these are conventionally defined (i.e., in terms of the industrial classification of activities, such as transportation, wholesaling, retailing, advertising, etc.), do not bound the systems of innovation. This in not peculiar to services, but also true of 'manufacturing sectors' and their 'systems of innovation', which relate primarily to the production of tangible goods. Thus differences with innovation systems in manufacturing are more of degree than kind (Hughes and Wood, 2000). Instead, the systems of innovation involve a wide range of agents from many

different 'sectors' (often including both manufacturers and various service providers). An interesting feature of these systems is that the agents involved (and the inter-relationships between these agents) can change over time, thus the boundaries of the system are not fixed but are dynamic, and evolve.

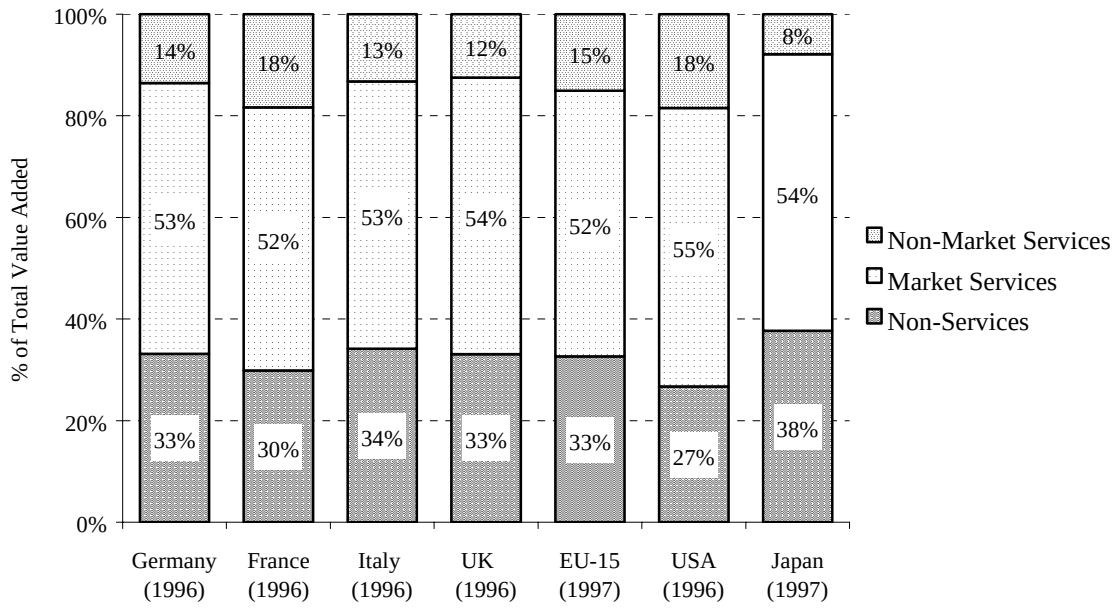
- We consider that 'systems of innovation' often develop around an identifiable problem (or opportunity), or sequences of sub-problems (or opportunities) that are themselves framed by a number of contingencies (including the regulatory, cultural and technological context). In this way, the problem sequence at the heart of the 'system of innovation' becomes the focusing device (Rosenberg, 1976; Hughes, 1983) around which the system is developed. As the problem (or opportunity) changes, or is redefined, so the system can change, changing the agents involved and the relations between these agents (Coombs et al., 2001). One important implication of this view is that firms can take a leading role in assembling innovation systems in the pursuit of their own competitive advantage. Innovation systems at this level are to a substantial degree transient, they evolve as the problems of the moment evolve. Consequently, the important issues addressed in this paper relate to the dynamics of the construction of innovation systems from the interaction of multiple agencies.

Section 1 Services – What Are They?

That advanced economies are service economies is well known. According to official statistics, services account for roughly two-thirds of GDP and employment in Europe (Eurostat, 1999), shares that are increasing, whereas those of manufacturing are in decline. Similar patterns exist for North America and Japan (Figure 1)

Statements of this kind raise immediately the problem of definition and classification, which is bound to be arbitrary to a degree. Services are usually defined negatively (Riddle, 1986) – as the 'residual' (Clark, 1940) or 'tertiary' sector (Fisher, 1939), as everything that is not agriculture or other extractive activities (the primary sector), and not manufacturing (the secondary sector), which is concerned with the production of tangible goods (Hill, 1977; Miles, 1996). This 'services are not' approach has developed into a widespread prejudice, that services are non-productive and ephemeral, whereas the 'real economy' is manufacturing (and agriculture, mining, etc.). Yet, as we have seen, the 'residual' dominates employment and value added in the developed world (although measurement of output from services is notoriously difficult).

Figure 1:
The Composition of Value Added in Europe, the US and Japan



Source: Eurostat, 1999, Tables 3.1 and 3.2

Even the definition of services as intangibles - as 'The fruits of economic activity that you can't drop on your foot' (Pennant Rea and Emmott, 1983) – is negative (and contested – see Hill, 1999); it is services as producers or providers of everything that is not tangible. Yet the absence of outputs that are independent physical entities is an important characteristic of most services. In manufacturing there is not normally confusion between the process of production and the outcome – the product, which has led to the conventional dichotomy of

process and product innovation. In services, the same term is used to denote both the process and the outcome. In short, the process is often indistinguishable from the product.[1]

Characteristics such as these encourage us to question the standard conceptualisations that are used in economics and innovation studies, but which have been developed essentially in the context of manufacturing. This brings us to the differentiated nature of services, and the multiple ways that service activities can be defined, which are central to an understanding of the complexities of innovation systems in services. One way to explore this is to enquire into the nature of the productive transformations through which services create economic value added. All productive processes relate to particular activities and transform combinations of material, energy and information into new more highly valued combinations of these elements. The difference in economic value that follows is what the economist measures as value added, the overall measure of work done in the process. Objectively, transformations are of three kinds: of the physical form of materials, energy and information; of the location in space of those elements; and, in the temporal availability of those elements. Thus a first approach to defining and classifying services is to ask what is changed (or transformed) by the service and how? Agriculture and other extractive activities extract raw materials from the earth; manufacturing transforms raw materials, semi-manufactures and energy into end products (which then provide consumer or producer services). Service activities, meanwhile, can be understood in terms of a dual taxonomy of relations, first, distinguishing what is transformed (i.e., a person, an object or information), and secondly distinguishing the nature of that transformation (be it physical, spatial and/or temporal) (Hill, 1977; Lovelock, 1983; Miles, 1996). Thus there are activities that transform physical objects (e.g., physical repair and maintenance services for automobiles or computers, and transport services which move things in space) or information (e.g., banking and financial services) or people (e.g., barbershops, hospital and passenger transport services).

A further complication is consumers' individual and collective interpretation of the nature of the service activity, and how this (subjective) interpretation impacts upon the nature of the service provided. For example, objectively, cosmetic surgery provides a physical transformation of the patient, but a successful (or unsuccessful) outcome is likely to have a profound (subjective) impact on the patient's mental or emotional state. Similarly, objectively a train journey is a physical movement in space, but subjectively it may give pleasure or discomfort. Many services are bought less for their 'objective' transformations than for the subjective interpretations associated with their provision. For example, a meal with others in a restaurant is rarely about nutrition alone.

Many service providers realise that they are in the business of providing more than objective physical, temporal or spatial transformations, especially when people (and their treasured possessions) are the object of the service. The subjective experience of the service is therefore something to be actively managed, for it can be fundamental to the value attached by the consumer to the service provided. For example, the décor and cleanliness of the carriage, the size and comfort of the seats, the number (and behaviour) of other passengers, the spacing between seats, and the availability and quality of the refreshments may all impact significantly on the perceived quality of a train journey. One way to consider these issues is to ask whether the service has a recognisable core and periphery. Admittedly, for some services, there may be no discernable core or periphery, or at least the interpretation of core and periphery can vary between provider and consumer, or between users, but for those to which the distinction applies, this can be akin to distinguishing the function and form of a

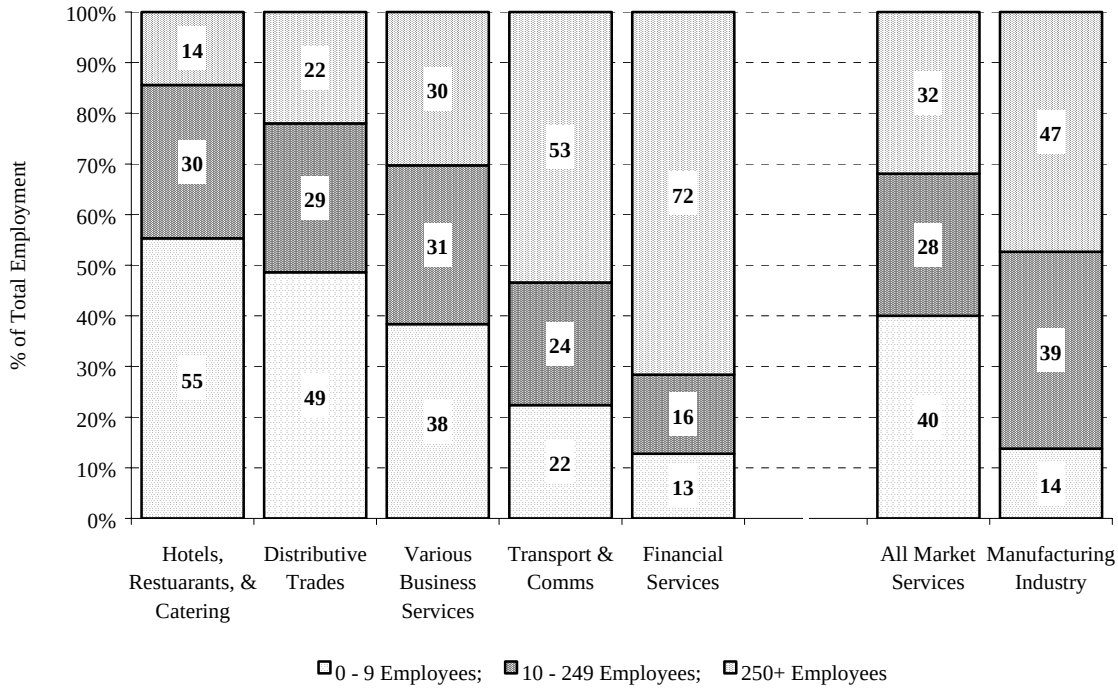
[1] This said, it can still be useful to make the conceptual distinction between the service process and the service outcome.

product. For example, the core function of a transport services is the movement of people or goods from one place to another, but the peripheral form of the service can vary enormously, from first class luxury to very basic travel arrangements.

Notable also in this example is that the core function of the services is normally provided without the active participation of the consumers. This is significant, because it is sometimes insisted upon that services are relational. That is: 'Services involve (simultaneous) *relationships* between producers and consumer. There cannot be a producer without a consumer. A service must be provided *to* another economic unit' (Hill, 1999, p. 441, emphasis in original). This relational aspect of services relates to the non-storability of service outputs (as they lack an autonomous physical existence – Gallouj and Weinstein, 1997). It also brings to the fore the interactive aspects of services and suggests consumers actively participate in the provision of service (i.e., service co-production). However, this is an oversimplification or overgeneralization. Although 'classic services' rely on the simultaneous and conscious participation of both the service provider and the service user for the execution of the service, this is not true of all services. Services can be available whether they are used or not, they are not always produced to order. Insurance and scheduled transport services are examples of this. Moreover, the extent to which consumers *actively* participate in the provision of the service is highly variable, but can be nil.

The nature of services, and the transformations they provide, also tends to have a significant bearing on their organisational form. Traditional services, which mainly undertake non-storable physical transformations, have tended to need to locate close to their consumers, and as consumers are widely distributed over space, so these services have tended to be supplied by small-scale local providers. Technological and other developments have however reduced the power of location for many services. As consumers become more mobile through access to transport services (and especially private cars), so retailers have exploited the potential economies of scale in large retail complexes. And as information technologies and networks have developed, so have new forms of co-ordination and delivery. Where traditionally most services were provided locally, with consumers often coming to the service provider, now many services are provided at arms length, for example over the telephone or through the Internet. Arms length provision typically allows the exploitation of economies of scale, which provide advantages over traditional, local provision. Developments in the banking and insurance industries are a good example of this, with a change from the provision of services through branches, to the increased use of telephone and the Internet. This encourages the development of a separation between the 'front office' (which deals directly with customers) and the 'back office' that carries out the service processes. This division can be real or figurative, but the nature of the service, for example in terms of the economies of scale and divisibility of front and back office functions, can have a significant impact on its organisation, in terms of the size of the enterprise, the number of sites, and location of functions (see Figure 2). It is also apparent from this that many services can be seen as ongoing (technological) 'systems' (i.e., as processes), which only involve customers in occasional discrete events (each of which is a 'service encounter', or product).

Figure 2:
Employment by Enterprise Size in European Services, 1995



Source - Table 3.9 - Page 56, *Services in Europe*, Eurostat, 1999

This brings us to a further dimension, which has been used to distinguish different types of services, namely, the duration of the engagement between the service provider and service user. Some services involve long contact times between provider and client, but for others contact times are very short (Silvestrou et al, 1992; de Jong, 1994). To an extent, there is a relationship between contact times and the extent to which services are standardised or customised. Services that involve short contact times are typically highly standardised, or routine, and low cost (facilitated by a reliance on low skilled workers), but involve few if any customer specific changes. By contrast, those that involve long contact times tend to be specialised, and high cost (with a reliance on 'professional', high skilled workers); the service provided often varies considerably from customer to customer. There are of course many exceptions. Doctors in general practice, for example, are professionally skilled but tend to have relatively short contact times with patients. Moreover, technological, organisational, regulatory and market developments can transform these relationships, allowing new service providers opportunities to provide differentiated services, such as simplified shorter contact time services which are substantially cheaper than those provided by the conventional service providers (e.g., the introduction of a specialist conveyancing services for house buyers, which is significantly cheaper than conventional legal practices for this task). The introduction of hybrid forms of organisation, such as franchises and federations can have significant impacts on the nature of service provision.

We have surely said enough to convince the reader that classifying an activity as a particular type of service is not always straightforward. The result may be purely conventional and conditional. It is well known that the same kind of activity can be classed as manufacturing when it takes place within a firm but be classed as a service if it is bought in from an external

supplier. Our purpose in discussing these issues is to highlight the highly heterogeneous nature of services. Services contain far greater diversity than manufacturing, but – other than telecommunications and computer services, which have their own peculiarities – services have also received only a small fraction of the attention that scholars and policymakers have paid to manufacturing. Because of this diversity, we cannot expect a single pattern of innovation in services; instead, there is a strong need to comprehend their diversity and relate this to the innovation processes with which each kind of service is engaged.

1.1 Innovation in Services – Some Attempts at a Taxonomy

We turn now to the implications of this discussion for the problem of innovation in services as a prelude to introducing three specific case studies of innovation systems in services. In the Pavitt taxonomy (1984) for example, services are defined as passive recipients of innovations developed by the suppliers of artefacts. In many cases this may be an adequate depiction of events: many service providers are passive, they are adopters not innovators, and many services have negligible innovation content over long periods. However, this is certainly not the whole story. As Gallouj and Weinstein (1997) assert, the analysis of innovation in services is difficult because (1.) 'innovation theory has been developed essentially on the basis of analysis of *technological* innovation in *manufacturing* activities' (p. 537 – emphasis in original) and (2.) the 'fuzzy' nature of service outputs in which it can be difficult to distinguish the 'service product' from the background process, or organisation, of provision.[2] As the quality of service outputs is often very difficult to measure, it is difficult if not impossible to identify the improvements in efficiency that follow from innovations.

As ever with services, there is a danger of over-simplifying, for there are a number of innovation trajectories in services, which are unevenly distributed across service sectors and service firms. In recent years, innovation scholars have sought to develop taxonomies or typologies of services' innovation trajectories, in much the same way as Pavitt (1984) developed his famous taxonomy of technological activities essentially for manufacturers. Pavitt's taxonomy – with its emphasis on different sources of knowledge and sources of competitiveness - can be seen as one of the antecedents of the sectoral systems of innovation approach. An interesting contribution, therefore, is Miozzo and Soete's attempt to adapt the Pavitt taxonomy to services (see also: Ducatel 2000, Coombs and Miles, 2000). In the original version, Pavitt had characterised all private services as being supplier-dominated (i.e., as being dependent on technologies developed by their (manufacturing) suppliers).

Miozzo and Soete (2001) distinguished three categories of service businesses:

1. **Production-intensive, scale-intensive and network services.** These services are 'industrial' in that they involve considerable divisions of labour with the simplification (and co-ordination) of production (and/or delivery) tasks, and the substitution of (skilled) labour by machines (and lower skilled labour). The application of this 'industrial' organization logic, and technological innovation, encourages the standardization of service outputs, or, in more sophisticated systems, the adaptation (through customization) of standard services to particular user needs. Within this group, two types of services can be distinguished:

[2] As mentioned earlier in services the term 'product' frequently denotes a process, such as a service package, a set of procedures or protocols, or an 'act'. This can also be associated with a close interaction between production and consumption, particularly when the service lacks an autonomous physical existence, exterior to both their producers and consumers or users. Thus there is typically a much hazier relationship between what is produced, and the process of production, in services than in manufacturing.

   a. **Network services**, which are dependent on information technology (IT) networks (e.g., banks, insurance and telecommunications). The development of ITs has facilitated improvements in the complexity, precision and quality of the services offered by these providers; they have especially facilitated customization, have had an important role in setting standards in many service activities, and have had a role in redefining the spatial division of labour over which these services are conducted.

   b. **Scale-intensive services**. These are dependent on physical networks (e.g., transport and travel services, and wholesale trade and distribution), which are less flexible than ITs in terms of facilitating customization, but do provide economies of scale and of scope. In these services there is also a heavy dependence on hardware technologies developed in the manufacturing sector.

2. **Specialised technology suppliers and science-based sectors**. These include such services as software and specialised business services, laboratory and design services. Firms tend to be small scale, and the main source of knowledge and technology is the innovative activity of the services themselves. Outputs are usually highly customised, often being designed for particular users (or groups of users).

3. **Supplier dominated sectors.** This is in effect a residual category, of services that remain 'backward' adopters of technologies developed by manufacturers. According to Soete and Miozzo, major examples include the public or collective services (education, health care, administration), and personal services (food and drink, repair businesses, hairdressers, etc.), together with retailing.

Evangelista (2000) makes a similar contribution, although grounded in more empirical evidence. Evangelista distinguishes between: '**technology users**' (which resemble Pavitt's 'supplier dominated' sectors); '**science and technology-based services**' – such as R&D, engineering and computer services, which are akin to Miozzo and Soete's specialist suppliers; '**interactive and IT based services**' – such as financial services and advertising, which are based on information processing and have high investments in IT systems; and '**technical consultancy**' – which combine the characteristics of 'science and technology based services' with those of 'interactive and IT based services'.

These contributions are useful in distinguishing types of services with regard to their technological activities and, by extension, organisational arrangements. Moreover, the identification of scale intensive and network services brings to the fore the question of regulation, which is particularly significant in shaping the provision of some services, especially those that are considered 'natural monopolies'. It will be clear that the regulatory environment for services will also play an important role in shaping service innovation systems.

However, Evangelista's category of 'technology users' (or 'supplier-dominated services') contains a large residual of heterogeneous services, including both private and public (or collective) services, the organisation of which is usually quite different, not only in their scale, but also in organisational logic. It is also surely erroneous for Miozzo and Soete to describe services such as health care as supplier dominated, when what matters is the complementarities between clinical innovation in the hospitals and the penumbra of externally supplied devices and drugs which support those activities. The relationship is one of symbiosis. The worlds of manufacturing and services are not parallel and independent, but mutually dependent. The same is true in retailing, amongst which large retailers often have

significant influences on their suppliers. An obvious example is UK supermarket chains – see section 2.3 below. These retailers set quality and environmental standards, and identify new products, for their suppliers (Harvey et al., 2002). As Coombs and Miles (1999) have rightly observed, studying service activities bring to the fore neglected aspects of innovation processes that are present across the whole economy.

Another contribution that seeks to characterise a variety of innovation styles but which does not privilege technological knowledge is that by Sundbo and Gallouj (2000). These authors, who consider innovation in services to be through 'loosely coupled systems', identify several patterns of innovation in services – from the classic R&D pattern (which they consider uncommon), through the service professional pattern, the organised strategic network pattern, the entrepreneurial pattern, and the artisanal pattern. Sundbo and Gallouj highlight the significance of interaction, arguing: 'The innovation process in services is to a large degree an interaction process, both externally (between providers and users) and internally (within the provider)'. They also argue that the service sectors are becoming more systematic in their innovation processes. Again, the wider point is that the nature of service activities, and the nature of the associated service innovation trajectories, is highly differentiated; it is problematic to speak of service innovation systems in highly generalised terms.

Section 2 Services and 'Sectoral Systems of Innovation'

We now turn to 'sectoral systems of innovation'. A sectoral system of innovation and production has been defined as 'a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products' (Malerba, 2002). These agents, which are characterised by specific learning processes, competences, beliefs, objectives, structures and behaviours, include organisations[3] and individuals.[4] They interact through processes of communication, exchange, cooperation, competition and command, but importantly these interactions are shaped by institutions (such as rules and regulations). The knowledge base of the sectoral systems is of central importance, as is demand, which may be existing, emerging or simply potential. Finally, sectoral systems are not static but dynamic: 'Over time a sectoral system undergoes processes of change and transformation through the co-evolution of its various elements' (Malerba, 2002).

The sectoral systems perspective is illuminating, not least because it draws attention to interactions between (knowledge-based) organisations and institutions, but also because of its emphasis on dynamics and transformations. However, there may be difficulties in applying the perspective to services, or alternatively the application of the perspective to services may highlight some problems with the perspective. One difficulty arises in defining a 'sector' by its products (or outputs) and, by extension, bounding the sector by the inputs (and agents) required to generate those products. Services, as we have emphasised, are essentially *processes* that cannot be easily disentangled from the 'product outcomes' derived from those processes. Thus, for example, all forms of transport move people or objects between places (the outcome is movement in space), but the processes involved in air, water and land transport can be quite different. This raises the question of how appropriate a conventional sectoral approach (defined on the basis of the standard industrial classification) is to the study

[3] These organisations may be firms (e.g., users, producers and input suppliers) and non-firm organisations (e.g., universities, financial institutions, government agencies, trade unions or technical associations), including sub units of larger organisations (e.g., R&D or production departments) and groups of organisations (e.g., industry associations).

[4] Such as consumers, entrepreneurs and scientists.

of services and their 'systems of innovation'. Rather than study innovation within conventional 'sectors', it may make more sense to map out 'systems of innovation' that cut across sectors, including both manufacturing and service activities, as these are conventionally defined.

Our work demonstrates that services are involved in multiple and complementary transformations that transcend any simple definition of a sector. These transformations involve both manufacturers (of tangible equipment) and providers of intangible and relational services. The corollary of this is that product defined 'sectors' and 'sectoral systems of innovation', focused as these are on the production (i.e., manufacturing) of goods, may provide a rather partial or blinkered understanding of the development of the 'sector' and its products. For example, defined along conventional sectoral lines, a study of the 'sectoral system' of commercial airliner production (perhaps within the wider 'aerospace' or 'transport equipment' 'sectors') is likely to highlight (and privilege) the technical challenges fundamental to the development of quieter and more fuel-efficient airliners. But arguably this provides a narrow viewpoint on the development of the industry. The development by Airbus of the A380 'super jumbo' is undoubtedly the most significant innovation from the commercial airliner industry for many years, but the development of that aircraft cannot be properly understood without extending 'the system' to incorporate airlines, passenger preferences, airports (including their capacity problems), and the regulatory regime (for both safety and competition). Thus a wider understanding necessitates incorporating within the 'system' activities conventionally classified in separate manufacturing and services 'sectors'.

We further contend that within each conventional 'sector' there are commonly multiple, overlapping 'systems of innovation'. These shape the revealed innovative performance of different agents active within each (conventional) 'sector'. These conclusions are drawn from our studies within the ESSY project of aspects of services innovation. The emphasis is on 'aspects of' innovation because we did not attempt all-embracing studies of our 'sectors' (i.e., airports, health care and retailing), each of which is large, complex and multi-faceted. Furthermore, we do not claim these services (or the aspects of them that we investigated) are representative of the wider 'service sector'. Instead, our research has focused on particular activities within these wider activities. In so doing, we studied three very different service activities. Within airports, air traffic control activities are 'classic services', that is they are co-produced by the provider and user acting together in real time. By contrast, in health services, the insertion of intra-ocular lens is a service provided by the producer for the passive recipient (it is akin to a repair service). Within retailing, supermarkets involve the consumers to the extent that they provide a significant part of the labour for the service (through self-selecting goods and self-delivery from shop to home). This focus on particular activities has allowed us to investigate processes of interaction and interdependency, classic properties of systems, which we would not have been able to investigate had we taken a broader approach to our research. Below we highlight some of the main findings from each of these studies.

2.1 Airports and the Creation of Runway Capacity[5]

For our work on airports, we focused on the central problem of runway capacity, and especially the problem of how to 'squeeze out' an ever-increasing throughput of aircraft using the existing runways at Europe's busiest and most congested airports – i.e., Frankfurt,

[5] This section draws on Tether and Metcalfe (2001)

London Heathrow and London Gatwick. We consider that our detailed investigation has contributed to developing our understanding of several conceptually interesting matters that relate to the underlying 'systems of innovation'. In brief, these are:

1. The fact that runway operations are co-produced services, based on institutions and instituted practices. Consequently, even in the absence of innovation, there are interesting questions about how 'the system' is co-ordinated.

2. Secondly there are the processes of innovation, both in terms of the search for capacity improvements and the actual implementation of the innovations. For both of these there is clearly a learning process, and particularly one dependent on co-operation between the service provider and the service users. Also prominent is significant procedural change, or 'soft innovation', which complements innovation through the adoption of capital equipment.

3. Thirdly, there is the apparent transformation of the innovation system over time, which relates to the gradual change in the sources of knowledge used for innovation. This has changed the participants in, and thus the boundaries of, the 'system of innovation'.

Co-Production, Institutions and the Distributed Process of Capacity Assessment

Air traffic services, including runway operations, are classic services – they are both intangible and 'co-produced'. This means the service cannot be stored, and is produced (or operated) jointly, consciously, and in real time, by the provider (in this case air traffic control - ATC) and the service users (the airline pilots). Co-production means efficient operations must be developed through negotiation and mutual understanding between the provider and user, particularly within the context of institutions and instituted practices.

'Slot rules' are particularly important and interesting institutions, as they influence how the 'system' operates. They have been instituted because of excess demand – especially at peak times - for the use of the airports, and give the users (airlines) security in their rights of access. They also stabilise practice (i.e., scheduling) and demand. However, they and other institutions also build significant rigidities into the system. For example, airlines are reluctant to change their standard operating practices (SOPs) to suit the needs of individual airports, especially as international SOPs are followed for insurance and licensing purposes. The processes of capacity assessment and slot allocation are both instituted and distributed between agents (i.e., provider and user). Partially, this reflect the fact that capacity is a compromise between the traffic throughput and the average delay, and thus between service quantity and quality, but it also reflects the importance of capacity analysis and slot allocation at congested airports. Again, this situation contrasts with conventional production activities, in which the producer controls and can change – unilaterally - the extent and organisation of production. Co-production thus highlights the restricted nature of the potential paths of change, as it is pointless to seek to impose change that is unacceptable to all the co-producing agents.

This sector illustrates an important theme that institutional change can be at the very core of innovation. One 'innovation' we discuss is the 'bunching of aircraft' by size into a more efficient sequence than that provided on a 'first come first served' (FCFS) basis. For example, if heavy, medium and small aircraft are denoted H, M and S respectively, and the original FCFS sequence of aircraft landing (or departing) is H S M H S M, it is more efficient to process these in the order S S M M H H. But essential to this re-sequencing (or

'bunching') is abandoning the principle (or institution) of FCFS. To abandon this principle the users had to be persuaded of the benefits, but also provided with safeguards. This meant the introduction of new rules, which effect a balance between the benefits and the disruption of the re-sequencing procedure.

Learning by Co-Operating and the Significance of Procedural Change

Secondly, we investigated the 'learning' processes behind the improving efficiency of runway operations at Frankfurt, Heathrow, Gatwick, three highly congested airports. The remarkable feature of these airports is that their runway efficiency has increased significantly over the years, despite being 'full' for most of that period, and despite retaining the same basic runway infrastructure. That is, they have not responded to the need for increased capacity simply by constructing new runways (because they have not been permitted to). This increased capacity through the same infrastructure is largely due to learning processes and procedural change that have improved utilisation of the existing infrastructure.

Because the service is co-produced, innovation is dependent on 'learning by co-operating', where 'co-operation' has the dual meanings of (1.) operating jointly and (2.) the harmonious search for mutually acceptable solutions. Thus where 'learning-by-doing' is an activity confined to the producer, and 'learning-by-using' is an activity confined to the user, where each has, respectively, autonomy over how the product (a third, independent, physical entity) is produced or used, this is not the case with 'learning-by-co-operating'. Instead, changes have to be negotiated rather than merely implemented. In this, 'learning by co-operating' shares commonalities with Lundvall's (1988) 'learning-by-interacting'. But with Lundvall's learning the producer normally refines the product to better reflect users needs, yet retains discretion over the final definition of the product. 'Learning by co-operating' is perhaps an extreme form of 'learning by interacting' in which the producer's discretion is severely curtailed. Whether a change is implemented depends on whether or not it is mutually acceptable to the service provider and the service users. Consequently, learning-by-co-operating is based on a high degree of contextual knowledge about the nature of the co-produced service and the development of a 'shared mental model' (Denzau and North, 1994; Druskat and Pescosolido, 2002)or 'collective mind' (Weick and Roberts, 1993; Weick et al., 1999) about the activity, and the paths of possible change. As a form of learning it extends beyond (conscious) 'learning-by-doing/using', which in effect identifies the possible changes that might be made (the possibility space), to an understanding of the needs of the other actors involved in the co-production of the service. This understanding of others' interests then reduces the number of real options for change within the possibility space.

This brings us to the second meaning of co-operating - the search for mutually acceptable solutions. Through the understanding generated by the first form of co-operating, the service provider and service users effectively narrow the options for change to those that are mutually acceptable. This does not mean all of the possible paths are identified, or their implications fully understood, but it is through this second form of 'learning by co-operating' that the service provider and service users set out to jointly explore mutually acceptable pathways to improving the operation of the 'system'. Importantly, at congested airports this co-operative search is conducted with the understanding that the airport is full, or very close to being full, but there is also constant pressure to expand capacity due to increasing demand. Within this context, each year a small number of opportunities to achieve small improvements to operations are found, negotiated, and implemented.

This brings to the fore the significance of negotiated procedural change as a source of capacity creation (or more generally efficiency saving), both in its own right and as a complement to the incorporation of new equipment. This 'soft side' of innovation has tended to be neglected by scholars of innovation, who have instead concentrated on hardware, yet the significance of procedural change is widely recognised in the technical literature on airports. Procedural changes are also central to the two innovations we investigated: the bunching of aircraft (which is outlined above), and the use of dual glideslopes for aircraft landing at Frankfurt airport. Admittedly, the second of these also requires advanced technologies to ensure separations between aircraft are maintained, but in both cases the innovations were based on procedural changes, which were in turn based on negotiated agreements between the service provider (air traffic control) and the users (airlines). Moreover, these procedural changes are to a large extent embedded within internationally agreed standard operating procedures.

The key point is that changes in operating procedures, which have provided efficiency, savings, are negotiated not dictated. Many lines of change are resisted, because vested interests make them unacceptable. Thus not only is it important to know what might be done, but it is also important to know what is (likely to be) acceptable. Ultimately, a central problem in 'knowing' the capacity of the runways is that this depends on how flexible the basic instituted practices are to change, which itself cannot be 'known' as the flexibility of these practices can change over time.

Changing Sources of Knowledge for Innovation and Evolving 'System' Boundaries

A third interesting feature of the study is the gradual, but apparent, transformation of the sources of knowledge used for innovation. Prior to the 1970s runway capacity was not a problem, whilst in the 1970s, 1980s and early 1990s capacity was increasingly understood and improved, but largely on the basis of direct operating experience and observations. Consequently, during this period, capacity enhancing innovations were largely dependent on context dependent operating knowledge, combined with an understanding of which changes to the existing procedures would be mutually acceptable to the service provider and service users (i.e., as outlined above). But as the scope for 'simple' procedural changes has diminished (in the 1990s), the search for continued improvements to the efficiency of operations has led to new innovation trajectories, which have involved new knowledge bases and new agents.

One such development is the further refinement of existing procedures through the use of sophisticated information technology 'decision support tools'. An example is the Final Approach Separation Tool (FAST), which assists air traffic controllers in maintaining minimal separations between arriving aircraft. Development of the FAST tool began around 1990, but was only implemented ten years later. This reflects the difficult of developing computer tools that not only match, but outperform, the heuristically based methods (i.e., rules of thumb) applied by experienced air traffic controllers.

A second new innovation trajectory is the detailed assessment of the fundamental institutions underlying runway operations, and most notably the length of separations between aircraft required due to the aircraft wake vortices. These separations 'are based more on experience than scientific research' (CAA, 1993), but as demand has increased so pressure to use the minimum safe separations has grown, because if the separations are too wide then valuable runway time and hence capacity is being lost. Consequently, much more scientific research

is now being undertaken into the nature of aircraft wake vortices, with the aim of reducing the necessary separations.

The broader point is that these new trajectories of innovation are involving both new types of knowledge (e.g., mathematical modelling, computer science, formal operations research and scientific knowledge of physics) and new agents (e.g., universities, specialist firms, public sector aerospace laboratories, etc.) in the 'system of innovation'. Thus the distribution of knowledge in the system is changing, with an increasing component of the research and development now being conducted off-site, in both public sector agencies (such as the national and pan European aerospace laboratories and aviation authorities), universities (computer science, operational research and physics departments) and in private companies. Some companies that have emerged to serve this growing industry, but others are longstanding. All are from outside the 'airports sector' or 'aviation sector' as conventionally defined.

Thus there is an evolution in the state and nature of knowledge about airside operations at airports. Knowledge is increasingly codified (in complex ways, for example, thorough the use of simulations) and is increasingly based on formal methods as well as experience. None the less it has been difficult for the 'codified formal approach' to catch up and surpass the tacit experience based knowledge that informed operations and innovation in the past. But there was nothing inevitable about this transformation (at least not with respect to its timing). If more runways were built there would be much less incentive to adopt innovation trajectories based on maximising the efficiency of the existing facilities, and the new knowledge and agents associated with this trajectory would not have been brought into 'the system'. Thus the nature of the knowledge used, and the agents involved, is in part a reflection of the contingent problem – and a willingness to address the problem - of inadequate runway capacity in the face of incessantly increasing demand for more flights.

2.2 Heath Service and the Case of Intra-Ocular Lenses[6]

Like the study on airports, the study on health care focused on one particular 'problem area'; restoring sight to patients with severe cataracts. In particular, the study concerns the emergence of a 'system of innovation' around the development of the intra-ocular lens (IOL). This is an example of a 'system of innovation' in knowledge based medical services, and more specifically in the field of ophthalmology.

As a distinct field of medical practice, ophthalmology has been the focus of major technological changes in the past four decades. Separate markets have been developed for the treatment of glaucoma, for the treatment of short and long sight through refractive surgery, and for the treatment of cataracts. In each case new procedures have transformed service provision, and underpinning these treatments has been a long sequence of complementary innovations - in materials, equipment and drugs and in the operative technique to perform the service. The study of the intra-ocular lens provides the opportunity to follow the innovation process – and the emergence of a 'system of innovation' - in a way that draws attention to the interdependence between artefact and service innovations in a field of rapidly changing medical knowledge.

To summarise the main findings we simply state that the innovation system associated with the intra-ocular lens has radically transformed the conception and delivery of a major medical

[6] This section draws on Metcalfe and James (2001)

service, namely the removal of cataracts combined with their replacement by a functioning lens. This has brought great benefit to countless patients and has greatly increased the efficiency and effectiveness with which the clinical procedure is carried out. It has been achieved by the creativity of individual clinicians combined with the development of a transnational medical-industrial complex. Over time, the innovation system has been radically transformed, from its origins in the work and craft technique of 'hero-surgeons', in a few hospitals to one that is a routinised procedure capable now of being effected in a local medical centre by clinician nursing staff. This reflects a fundamental transformation of a service activity and its skill base.

In summary, the main findings of the study are as follows:

- Radical effects on the delivery of health services have followed from the introduction of IOLs. For the patient, an operation that formerly required months of incapacity is now recovered from in a matter of hours. For the health service, there has been an enormous increase in capital and labour productivity associated with the increased patient throughput. Corresponding to these surface effects have been major changes in the education and training processes for nurses and clinicians and the emergence of a new division of labour between nurses and clinicians in the performance of the operation. However, not all the methods have proved successful, and, in many cases, lenses have had to be removed or in extreme cases eyesight has been lost. As with many medical procedures, the experimental costs are necessarily born by the patients. Cataract surgery is a branch of human engineering, it is not based on a predictive science.

- The innovation has underpinned the development of an international medical-industrial complex that drives the innovation process and connects together clinicians with firms in what has evolved into a science-based industry. In effect, intra-ocular lens implants have evolved into a commodity provided in a market, albeit a highly regulated one that, in different counties, mixes differently public and private provision.

- The 'system of innovation' is sustained by and develops through the interaction between different national ophthalmic health providers, each with their own funding and other characteristics, that are connected by international networks of clinicians and the transnational health companies which develop and market their ideas.

- The innovation process around IOLs illustrates multiple facets of the innovation process including: the importance of complementary developments in technology, the role of serendipity, an often profound hostility to new ideas by established professionals, competing and evolving lens design configurations and operative techniques, and a sequence of incremental innovations gradually improving the performance of the implants. As is so often the case, the potential of an innovation takes many years to realise, with many failures and abortive paths of development before a dominant design configuration is established. It is for this reason that a historical perspective is so helpful in establishing the processes at work in generating the innovation sequence.

- The dynamic character of the distributed innovation process for IOL based cataract surgery. This system did not exist prior to the initial 'radical' innovation, and it has co-evolved with the growth of knowledge and practice. We understand a dynamic system of innovation to be one in which actors, relationships and boundaries change over time. The change may be stimulated either from the outside (for instance, by a change in regulatory regime, government policy or competitor behaviour) or from within by the activity of the

actors themselves. Moreover, there are important processes of institutionalisation which impact on the structure of the system, and the diffusion of the innovation.

- The unique role of the commercial firm to act as the locus of combinatorial capabilities, connecting together the elements of the innovation system in the search for competitive advantage. The key point is that competition leads to connection, and connection can lead to collaboration. In this process of innovation system building, problems play an important role as focal points for interaction between different actors. Moreover, the solution to one problem opens up new problems so that the growth of knowledge is properly described as autocatalytic. Solutions to one problem raise new problems in a sequential fashion.

It is apparent that this 'system of innovation' is constituted by elements at multiple levels - transnational and national, sectoral and regional - but what matters for the actual course of innovation is the micro systemic element. As with the airports' case, the innovations generated by the system did not occur 'naturally' at any level, rather they were created around cumulative sequences of problems and involved shifting patterns of interaction as new problems emerged and drew upon different kinds of specialised knowledge for their solution. To understand how these processes work we undertook a detailed investigation of the micro innovation system and analysed how it was constructed around connected problem sequences. Who formulates the problem sequence is thus a key issue in the evolution of these innovation systems.

National organisations, for example in the form of health care systems with their inherent differences, have certainly framed the development of IOLs but the framing is contingent. More constraining are the established theories and practices that lie within particular branches of ophthalmic practice, and the links between surgeons and major ophthalmic companies. However, these constraints spill over national boundaries and develop over time as the innovation is diffused within different healthcare systems. Thus while the first two decades of the innovation of the IOL are essentially a European story, the next three decades are told in the United States, where the major ophthalmic multinationals rise to dominate the industry. All of these firms have a major marketing and distributive presence in Europe but the preponderance of their innovation activity remains in North America. This geographic shift marks a more subtle development in this innovation system: from one centred around hero surgeons who publish and patent within a well defined community of hospital and clinical practice, to one in which large firms dominate and channel the innovation process along established lines. This does not mean that the surgeons are rendered unimportant, but it does mean that their position and role in the innovation process is now very different to how it was in the early years.

2.3 Retailing and the Transformation of Distribution[7]

The study of retailing, which compares the UK situation with that in Sweden, takes a broadly similar approach to that used in the study of airports and health care. This study focused on a central business 'problem' in the organisation of supermarket retailing but took a broader and longer-term view of the transformation of grocery distribution from food producers to end-consumers. Like the other studies, the aim was not to provide a complete examination of the 'retail sector', nor was the study narrowly confined to 'retailing' as that activity is

[7] This section draws on Harvey et al. (2001).

conventionally defined. Indeed, the comparison between the UK and Sweden in the transformation of grocery distribution and retailing was designed to reveal the dynamics of variation, in terms of the relations between the different economic agents who are conventionally understood to be active in different aspects of retailing.

This study demonstrates how changes in relations between consumers, retailers, manufacturers, logistics, and primary producers brought about very different types of innovations, and innovation potentials, in the two countries. Although there are some fundamental physical, geographical and economic differences (such the size and distribution of the population, and the level and distribution of income) which contribute to the different national patterns of transformation, the comparison of the two countries highlights the factors that underpin the process of variation in different socio-economic spaces (rather than taking these as given). Thus, in this analysis, retailing is shown to be a node, ever more critical, in an evolving innovation complex involving actors and organisations from a variety of economic spheres.

One of the key aspects of national differences is the path dependent and instituted nature of the trajectories of transformation. The Swedish starting point was very different to that of the UK, for although its strong co-operative movement certainly had a parallel in the UK, they developed along substantially different lines, becoming the general pattern in Sweden, whilst in the UK co-operatives focused on working class demand. This in turn underlies the central and compelling difference between the two retail configurations that persists to this day, although both configurations share strikingly high levels of concentration.

In the UK the dominant retail supermarkets are integrated businesses. This configuration has encouraged the total and centralised integration of grocery distribution from control of primary and secondary producers to retailing itself, and has included the bypassing of intermediates, most notably wholesalers. Consequently, the dominant retailers orchestrate not only retailing activities, but also exert a significant hold on producers and distributors. This orchestration has great influence on the activities of others with different capabilities and technologies, such as logistics companies, food product manufacturers and farmers. In Sweden, by contrast, the large retailers are not single firms, but federations of end-retailers. Thus in Sweden the locus of centralisation is not, as in the UK, at the retail end, but at the intermediary, wholesale, node of the complex. From this structural difference much flows in terms of innovation potentialities, patterns of collaboration and concertation, and the engagement of different knowledge bases. For example, the Swedish configuration has led to a much more decentralised pattern of local and small scale production, fostering organics, and has blocked the innovation potential of an electronic point of sale (EPOS) driven supply chain that is such a prominent feature of 'the system' in the UK.

A major conclusion that can be drawn from this path dependent character of transformation in different economic spaces is the intimate linkage between industrial organisation – and changes in this - and innovation processes and potentialities. This brings to the fore the inter-linkage between business models, organisation and technologies. When comparing the 'first revolution' in retailing - the emergence of the global brand manufacturers - with the 'second revolution' – the dominance of large-scale supermarket enterprises - there are clear differences between the processes of innovation, the objects of innovation, and markets for innovation. Viewed as distributed processes of innovation (Coombs et al., 2001) it is apparent that the nature of the distributedness changes. In the first, the key points of articulation were between manufacturers, organic chemists (with a university base), farmers, the engineering of continuous flow production, and marketing. In the second, the retailer

becomes the primary orchestrator of the different economic agents with different capabilities stretching from biotechnology to informatics.

But not only have each of these transformations involved new patterns of distributed innovation activity, they have also led to the emergence of new classes of economic agent (e.g. logistics companies, specialist software houses) or radical transformations of existing classes of economic agent (e.g. food manufacturers, retailers, farmers, consumers). This has changed the relations between classes of economic agent, however, these changed relations are most prominent between rather than within 'sectors' as these are conventionally defined. These changed relations underpin the emergence of new fields of innovation, new forms of co-operation, and the development of different knowledge bases. Thus innovation processes within retail organisations – such as the introduction of scanning and electronic point of sale (EPOS) systems at checkouts – can only be fully understood as a node of innovation within a much broader innovation complex extending beyond retailing as a distinct activity. For despite many of the key capabilities remaining 'outside' the retailer and the 'retail sector', it is through their orchestrating role that – in the UK - retailers have co-ordinated these external capabilities and integrated them into the innovation process. It is in this context of the pursuit of individual and group competitive advantage – that retailers be seen to assemble the innovation system by articulating the interactions between many organisations with distinctive capabilities. This division of innovative labour is not static but rather it is continually evolving, it is at the same time replicated and constructed.

The emergence of the retailer as a dominant player leads to another important reflection on the role of multinationals in this innovation complex. Two very different models of globalisation are at play. The first model is driven by the branded manufacturers (Nestlé, Unilever, Danone, Kellogg, Campbell), which produce generic products to exploit economies of scale in manufacturing, marketing and product design. Although there are products targeted on specific national market segments, typically the target is the 'global consumer'. By contrast, the second model is a retailer-dominated configuration, driven by the front-end interface with the consumer. This has developed and draws upon a knowledge base that is highly focused on socio-economic profiles of consumers and differentiations in consumers within the 'catchment' areas of a particular retail store. In this model the branding is that of the retailer, and it is the branding of the whole basket of products and services, rather than the branding of specific products, or product categories. In the UK, supermarket own-label produce has become more and more focused on product differentiation and market segmentation. Meanwhile, and although nationally located, the supermarkets have become orchestrators of global supply chains, bringing new ranges of produce to the supermarket shelf. This creation of dedicated global supply chains tied into product and price differentiation is a very different model of 'globalisation' from the first model - that of the branded manufacturers (Harvey et al., 2002).

It should be emphasised that these two models of globalisation co-exist, although there is considerable tension and competition between them, especially at the points where their product markets intersect. Yet one does not simply replace the other. Many of the global brand manufacturers have responded to the emergence of retailer power and own-labelling by shrinking their product portfolio to concentrate on a core of global generic products. Conversely, the retailer model of globalisation is itself extending its scope, with Ahold of the Netherlands moving into Sweden, Walmart of the US coming to the UK, and Tesco of the UK moving into Eastern Europe and South East Asia. As yet this process of extension is only beginning (which in itself raises questions about why supermarkets did not

internationalise sooner) it remains to be seen whether and how the retailer-dominated configurations will adjust to very different consumer markets from those in which they emerged. It is still very uncertain how the uneasy co-existence between the two (evolving) models of globalisation will contest future economic spaces.

Finally, a striking aspect of the innovation complexes investigated in this study is that they are engaged 'from seed to mouth' in a diverse range of activities, which draw upon a diverse knowledge bases. There is certainly fundamental science (e.g., in genetics and biotechnology), but there is also engineering knowledge (e.g., in satellite tracking or in packaging with artificial atmospheres), operational knowledge (e.g., in logistics), design and market knowledge. Last, but not least, there is consumer knowledge, learning and beliefs, which have been of considerable significance in the recent food scares, and which have fundamentally altered the parameters of product innovation in Europe. Retailers have played a key role in articulating these diverse forms of knowledge as they have gained power and control over food provision. Food retailing therefore provides us with a rich ground for exploring processes of variation in innovation distributed across a multiplicity of different institutions and capabilities.

Section 3 Elements of 'Systems of Innovation'

From the definition provided by Malerba (2002 – see above) 'sectoral systems of innovation' are characterised by a set of attributes, which evolve over time and which identify system components and their mode of interaction. These attributes are: the knowledge base and learning processes; firms, non-firm organisations and networks; institutions; demand and geographical boundaries. This is a very large agenda, even for a slow moving and well defined and understood 'system of innovation'. Services, by contrast are vast, diverse, often rapidly changing, but little studied. Our studies have but scratched the surface of 'systems of innovation' in the service sector; we cannot claim to have undertaken a complete analysis, nor one that investigated a representative set of service activities. However, as the summaries provided above demonstrate, each of the studies provided interesting insights into the nature of innovation systems in service-orientated activities. Below, we highlight some of the main findings with respect to the various elements of innovation systems, although the strength of the 'systems' perspective is in understanding phenomena in their context – much is lost when 'systems' are deconstructed into their elements.

3.1 Knowledge Bases and Learning Processes

Traditionally services have been portrayed as mere adopters of technologies developed by manufacturers (Pavitt, 1984), but this is badly misleading. Our studies have emphasised the joint significance of technology in equipment (such as medical devices, radar at airports, scanners and sensors in logistics) and the skills of the operatives (medical surgeons and air traffic controllers). Certainly there is an interesting interplay between embodied and disembodied knowledge, and the boundaries between these can change. Moreover, as procedures or techniques become more familiar, they can be practised by less highly skilled people, as in the case of the intra-ocular lens. The main point, however, is the significance of technique, or procedure, alongside artefacts or devices. Technique and procedure are particularly significant in services, and have been largely overlooked in innovation studies that have focused on manufacturing.

The knowledge bases of services are diverse, but an interesting characteristic of the activities we have examined is how these can also change fundamentally over time. This is true of each of our cases. In airport runway capacity there has been a gradual shift from learning through experience and co-operation, to the use of formal and scientific knowledge, and specialist R&D type departments and companies with these knowledge bases. In the case of intra-ocular lenses these procedures were initially developed by highly skilled professionals (surgeons), but advances have since become the province of large, diversified medical firms. There has been a shift in the locus of knowledge/learning from the hospitals to the companies providing the devices and associated training. Thus in these cases there is a changing dynamic in the relationship between the sources of knowledge and the boundaries of the systems of innovation. In the retail case, integrated, computer based methods of management and control have transformed the use of logistics information with consequent changes for the skill base of the sector's management.

This brings us to the question of the boundaries of the systems of innovation, which we treat as evolving and not fixed, and which do not coincide with the conventional sectoral definitions. For example, retailing is only one activity in an extended chain of activities that transform raw materials into products and which distribute and market them to consumers. As a result the innovation system, which can be largely orchestrated by retailers, extends from producers to consumers, but also includes distribution, advertising, warehousing and many other activities. Similarly, with air traffic activities at airports, the 'system of innovation' involves air traffic control, the airport operator, and the airlines, but also aircraft manufacturers, specialist service and equipment suppliers, university researchers and others. Thus a narrow focus on 'airports' or 'retailing' presents a severely curtailed picture which fails to show the interactions and interdependencies that are a key feature of 'systems of innovation'.

3.2 Firms, Non-Firm Organizations and Networks

Although the classic mode of service provision is a vast array of fragmented small independent providers, often operating on a local basis, the service activities we investigated all have significant network relationships, which are also increasingly multinational. In each case, there are significant variations over time and or space in the nature of the organisations active in the systems of innovation.

In the case of intra ocular lenses the kinds of agencies involved and the relations between them have changed significantly over time as the innovation system has been constructed. Initially, the system involved professional clinicians working in the context of hospitals and associations of professional practitioners, but over time it has extended to include producers of ophthalmic devices, material suppliers, and managers of healthcare delivery systems. In the process, specific sets of overlapping networks have been created. Our conclusion is that competing ophthalmic supply firms have constructed their own 'local' innovation systems in the pursuit of competitive advantage in international markets. These local innovation systems draw upon the resources found within networks of ophthalmic clinicians, university science networks, and hospital management systems. The networks do not of themselves constitute innovation systems, rather the systemic effect is something articulated by the ophthalmic companies and changes as the companies' perception of the innovation problem also changes.

In the case of airports and the creation of runway capacity the 'system' initially involved the airport operator, air traffic control, the airlines and the aviation authority, but has been expanded in recent years as the sourcing of knowledge has changed. This has drawn in specialist firms, research institutes and university departments. Also important is the changing status of the agents involved in this system. In the UK and some other countries, privatisation has shifted the airlines, airport operator and air traffic control from the domain of publicly owned service providers, to being privately owned and governed by a commercial logic. This transformation is having implications for the way in which these agent inter-relate, and how they inter-relate with the other contributors to the system of innovation. For example, the UK air traffic control company is now seeking to sell its expertise in international markets, whilst it is also reducing its internal research capacity and increasingly outsourcing innovation related expertise from universities and specialist consultancy firms.

In the case of retailing, it can be seen that the contrasting nature of the firms in the UK (highly integrated businesses) and Sweden (federations and cooperative) has resulted in rather different patterns of innovation, and rather different loci of control over the 'production-distribution-retailing chains'.

Non-market organisations also have a significant impact through the regulation, which can impact directly and indirectly on the 'the systems of innovation', by encouraging some forms of innovation whilst restricting others. For example, in the case of the intra-ocular lens (IOL) the initial regulatory frameworks were provided by clinical norms often hostile to radical innovation. As the industry has matured so regulation from the Food and Drug Administration (FDA) in the USA and its European equivalents have assumed greater significance. Moreover, legal norms have come increasingly to constrain the relation between innovative medical practice and patients. Indeed, the inventor and innovator of the IOL retired from performing the procedure precisely because of fears of litigation at a time when the technology appeared to have hit a bottleneck.

3.3 Institutions

Institutions, 'the rules of the game' that constrain, co-ordinate and enable activity also play a central role, particularly in highly regulated services such as health care and air traffic operations. In the case of the intra-ocular lens, for example, the operation was initially conducted if the patient's score on the so-called 'Snellen test' was below 6/12. This shows the 'Snellen test' to be an important institution in 'the system', but also raises a number of questions, such as why the 'Snellen test' is used and not any other test, and why this particular threshold value is used, and who decided upon it. Thus not only are the institutions significant, but the process of institutionalisation is significant, as is potential conflict over the institutions. Moreover, as the scale with which the procedure is applied has increased, so clinicians have sought to complement an objective test with softer 'lifestyle' criteria such as the extent to which a candidate patient is socially and economically active.

In the case of airports (and retailing) 'slots' are used to provide access to the runways (and for delivery to supermarkets). At airports especially the means of slot allocation and retention is fundamental to the operation of the system. Airport slots are allocated and retained by non-market mechanisms, and they cannot be bought and sold. But if they were allocated by a market mechanism, such as by auction, this would have significant ramifications for airport operations. This would then impact upon the 'system of innovation', quite possibly making the search for additional throughput less important; instead the use of

larger aircraft (rather than more aircraft) would be encouraged. Clearly, institutions are crucial, but to understand the system it is not adequate to list them; it is necessary to understand how they came to be instituted, and how they influence behaviour. In the case of retailing, we need to develop a fuller understanding of why systems of provision developed in different ways. Why, for instance, does the Swedish system have an orientation to federations and co-operatives, whilst the UK system is dominated by integrated businesses. Why also have these different configurations tended to be rather national in orientation, rather than international?

3.4 Demand

The role of demand and how this is developed, or constructed, is very often under-explored in studies of innovation. Frequently, it is assumed that the good or service provided fulfils some basic need or want for which there is at least a latent demand. This demand is stimulated, first by the good or service becoming available then expanded through improvements in the quality or reductions in price. We suggest that demand side issues require urgent attention, especially in relation to how 'wants' or 'needs' are formed, and then expressed in terms of demand. For example, while the clinical need for the removal of cataracts is long standing and extensive in the population aged over 55, the expression of this in terms of demand for clinical services is very much influenced by the medical solutions available and the response of health care managers to the resource implications of enhanced demand. Thus the link between the patient and the service is mediated by a complex of instituted relations between clinical practice and health care management. In the case of airports we did not examine the level of demand – which is growing exogenously to the 'airport system'. However, the structure of demand – for instance in terms of the size distribution of aircraft – has important implications for the 'system of innovation'. If there were only one type of aircraft the problems faced would be very much simpler.

3.4 The Geographical Boundaries and International Performance Comparisons

Conventionally, most services are provided locally, and can to have strong cultural variations, but the services we examined were not typical in this regard. It is difficult to generalise about the boundaries of the system, for there are certainly local, national and global aspects. For example, in many ways air traffic operations are a global activity – operating practices are essentially the same the world over, and are agreed by international organisations. However, airports also tend to have their own individual problems, which require local solutions. These local solutions, meanwhile, must comply with standard international operating practices. As further airports in other locations confront the same problems, so solutions are transferred, at least partially. In the case of the intra ocular lens, the geographic locus of innovation activity has changed over times, from a European to a North American focus, but the practice is global, albeit operating in different contexts of national health care provision. With retailing there is a similar story. To a large extent practices are very similar across space (for instance the increasing use of sophisticated logistics), but there are also important and often subtle difference. Certainly none of these systems are strictly national in character, rather the local and the global intersect in relation to different aspects of the innovation process.

International performance comparisons of different innovation systems are also difficult to make. What is being compared, how broad should the consideration be, and over what timescale? What weight are we to give to local conditions that impinge on the innovation process. In each of our cases international differences exist but it is difficult to relate these to

innovation performance. For example, amongst airports, Paris' Charles de Gaulle has been permitted to construct new runways roughly in line with the increasing demand for flights. Because of this it performs well in terms of delays, but it has also had less need for the innovations and innovation processes that we have identified as responses to capacity constraints at London Heathrow and Frankfurt, where the airports have sought to make the most of the existing facilities.

Section 4 Innovation Systems as Problem or Opportunity Centred and Contingent

We end this paper by re-considering 'systems of innovation' as problem or opportunity centred and contingent. A system implies not just interaction, but also interdependence, and we consider that much of the existing literature on 'systems of innovation' fails to demonstrate the nature and function of any interdependence between the participating agents. The fundamental issue is to be clear on what interdependence involves and how it matters for the rate and direction of innovation. A 'national systems' approach is particularly broad in its view of innovation, seeking as it does to explain why the pattern of innovation (and specialisation) differs between countries.[8] Freeman (1987, p.1) originally defined a national system of innovation as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies'. Thus within Freeman's (and Nelson's (1993)) 'national systems' the systemic factors are things such as government (science and technology) policies and organisational support for technology and innovation, the extent and organisation of R&D within enterprises, the training and education systems, and the financial institutions. Lundvall (1992, p.12) also takes a broad view of national systems, including 'all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring'. However, arguably there is little that is systemic about these 'systems' (Freeman's use of the term network is notable). Interaction is largely assumed rather than researched, and there is even less evidence of inter-dependence.

The 'sectoral systems of innovation' approach (Malerba, 2002) has built upon the 'national systems' approach – arguing that technological fundamentals are at least as important as differences in national institutions. This is as true of service activities as it is of any other productive activities. This meso level approach builds on the work on technological families (Scherer, 1967) and on broad patterns of technological change - such as technological regimes, paradigms and trajectories, discussed by Dosi (1982), Nelson and Winter (1982), Pavitt (1984), and others - complementing these ideas with those from a resource or competence based view of the firm (Penrose, 1959, Foss and Knudsen, 1996).[9] However, whilst the 'sectoral systems' approach has tended to be more specific than the 'national systems' literature (in terms of the organisations and institutions included), the sectors still tend to be defined using conventional 'industries' as points of reference – e.g., chemicals, biotechnology, telecommunications.

In our work on systems of innovation in services (Tether and Metcalfe, 2001; Metcalfe and James, 2001; Harvey et al., 2001), we have taken a different approach. We have not attempted to study entire 'sectors' of service provision, but have instead focused on particular

[8] It is also primarily a policy-oriented approach. As Edquist (1997, p. 12) states: 'the importance of national systems of innovation has to do with the fact that they capture the important political and policy aspects of processes of innovation'.

[9] This emphasises the creation and selection of diversity amongst firms, which is itself the result of the path dependent accumulation of firm-specific (technological) knowledge and expertise. Thus the creation and accumulation of specific capabilities by innovating firms reinforces the value of their participation in the relationships which constitute the 'sectoral system'.

problems, innovations and wider transformations arising within the production of specific services. The definition of the underlying activity is the crucial step in this approach. The implications of these case studies for the 'systems of innovation' perspective are considerable. For such systems are, we argue, constituted by elements at multiple levels, transnational and national, sectoral and regional, but what matters for the actual course of innovation is their micro systemic element. The systems that generate innovations do not occur 'naturally' (or inevitably) at any level, rather they are created around cumulative sequences of problems (or opportunities)[10] and involve shifting patterns of interaction as new problems (or opportunities) emerge and draw upon different kinds of specialised knowledge for their solution. To understand how these processes work we need a far more detailed understanding of micro innovation systems and how they are constructed around connected problem (or opportunity) sequences.

In some cases the problem or opportunity is obvious – such as in the case of airports and the problem of insufficient runway capacity to meet (valuable) demand, and in the case of seeking a remedy to failing eyesight due to cataracts. In other cases the problem / opportunity is not so obvious – as in the case of retailing – and in such cases the problem / opportunity is a matter of interpretation that may need to be constructed, negotiated and even institutionalised. In UK retailing, the problem / opportunity might be interpreted as being how to gain and maintain primary access to consumers (against direct and indirect competitors). Notably, this has been achieved through the centralisation and control of distribution functions.

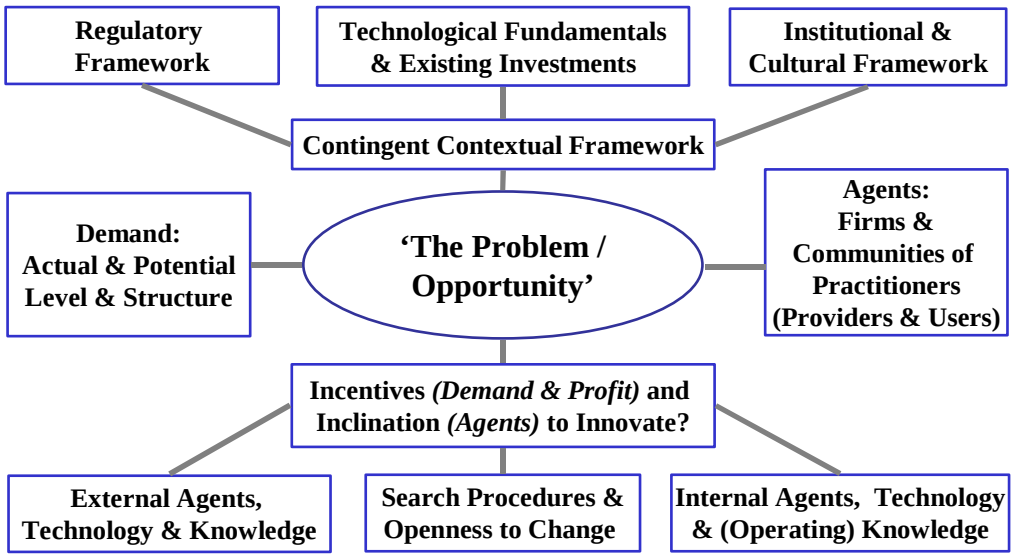
Importantly, the problem / opportunity is often contingent, not only on the technological fundamentals (and past sunk investments), but also on the regulatory and institutional constraints. For example, at airports such as Frankfurt and London Heathrow the problem of inadequate runway capacity would not exist (or at least would be very different) if, like Paris Charles de Gaulle, these airports were permitted to build new runways. It is because they have not that the pattern of innovation has followed a different road at these airports.

In Rosenberg's (1976) terms, the problem / opportunity is the 'focusing device'[11] around which the 'system of innovation' is constructed, but the 'system' is also framed by the contingencies – such as the regulatory framework. Thus the 'system of innovation' entails a division of labour, formed around a focal problem or opportunity, framed by contingencies, and energised to confront and provide solutions to particular system elements. The problem / opportunity does not necessarily define the solutions, or the 'solution pattern', but the contingencies are likely to restrict the scope of possible solutions

[10] In English the term 'problem' tends to have negative connotations, whilst the word 'opportunity' has positive connotations – we would prefer a neutral term, or one that has both positive and negative (and even ambiguous) connotations.

[11] Note also Hughes' (1983) concept of the 'reverse salient'.

Figure 3:
The 'System of Innovation' as Contingent and Problem / Opportunity Centred



The diagram above (Figure 3) attempts to represent this 'system of innovation', although, as with all such diagrams, there is a danger that it appears static rather than the dynamic. On the contrary, we emphasise that 'the system' is likely to evolve over time in terms of its components and their interactions. The problem / opportunity is not necessarily fixed, nor are the possible solutions Thus the 'system of innovation' is a *dynamic distributed process* (Coombs et al., 2001) into which new agents and new knowledge sources may be incorporated, and from which unnecessary agents and exhausted knowledge sources may be discarded.

This perspective brings to the fore various questions. What energises the 'system of innovation'? The answer depends upon the context but it is, we conjecture, the organisation(s) that ultimately deliver the service, for it is only these organisations that have the unique role of combining all the different innovation contributions for an explicit purpose. In the case of market based activities the primary stimulus is the search for business advantage – actual and potential, as perceived by the firms in the 'sector'. In other cases, non-market organisations play the critical role as they do in the airport's case study. Secondly, what is the nature and durability of the interactions and inter-dependencies within the system? By considering the system of innovation to be contingent and problem / opportunity based we can investigate interactions and interdependencies between the agents in much greater detail than is the case with broad national or industry studies. We can also investigate the patterns of resistance to innovation, as well as the patterns of 'successful' innovation, and the changing sources of knowledge used. Moreover, we can examine, where appropriate, the changing balances of dependency and power within the system, and assess how that relates to the observed pattern of activities and innovation (Coombs et al., 2001).

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