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Innovation Dynamics and the Role of Infrastructure

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Innovation Dynamics and the Role of Infrastructure

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The intellectual framework for the treatment of the innovation infrastructure draws heavily on a series of reports on the economics of standards, measurement and design, by Peter Swann, as well as on extensive discussion with him over the years. Paul Temple and Michael King have also made major contributions to the understanding and quantification of the impact of standards and of National Measurement System.

Executive Summary

This report shows how the role of the infrastructure – standards, measurement, accreditation, design and intellectual property – can be integrated into a quantitative model of the innovation system and used to help explain levels and changes in labour productivity and growth in turnover and employment. The summary focuses on the new results from the project, set out in more detail in Sections 5 and 6. The first two sections of the report provide contextual material on the UK innovation system, the nature and content of the infrastructure knowledge and the institutions that provide it.

Mixed modes of innovation, the typology of innovation practices developed and applied here, is constituted of six mixed modes, derived from many variables taken from the UK Innovation Survey. These are:

- Investing in intangibles
- Technology with IP innovating
- Using codified knowledge
- Wider (managerial) innovating
- Market-led innovating
- External process modernising.

The composition of the innovation modes, and the approach used to compute them, is set out in more detail in Section 4. Modes can be thought of as the underlying process of innovation, a bundle of activities undertaken jointly by firms, and whose working out generates well known indicators such as new product innovations, R&D spending and accessing external information, that are the partial indicators gathered from the innovation survey itself.

The mixed modes of innovation model used in this report can include indicators of the role and importance of the infrastructure at two levels of analysis: (a) firm level obtained from the UK innovation survey and (b) evidence external to the survey measured at a higher level of aggregation (i.e. industry or geographical location). The use of standards as a source of information, the propensity to invest in design and the use of a variety of forms of IP taken from the UK innovation survey are measured at enterprise level. External data is brought into play on the extent of metrology related knowledge, observed at industry level, and the intensity of accredited certification to a Quality Management Standard – ISO 2001 – observed at county level.

From Table 5.1, which reports on the modes computed from the most recently available survey, covering activities in the 2006-2008 period, we can see that design is part of the mode interpreted as firms investing in intangible investment. This mode groups together propensity to invest in the creation of knowledge assets: R&D, advanced machinery and IT, training (raising human capital) and marketing. These forms of investment, observed here at firm level, have a substantial overlap with the economy level intangible assets model developed for the NESTA innovation index and outlined in Section 2. A feasible strategy for innovation by businesses is to invest in the development of such intangibles, to create the internal knowledge base for future competitiveness, but also for developing novel products. Design capability enters into the mix of intangibles as a factor affecting the attractiveness of products to the market place, as a means of promoting efficiency in production and distribution, and also as a means of coordinating diverse internal and external resources as part of 'open innovation' (Acha 2005). Design also exhibits a modest degree of correlation with IP in a mode that represents own account technology development with a propensity to new-to-market product innovation.

The various types of intellectual property rights tend to group together in the own technology mode, coupled with intra-mural R&D (to a modest extent), and design, as noted above. When the modes are compiled with earlier instances of the UK Innovation Survey that included questions on the use of strategic IP, including speed to market, confidentiality agreements and design complexity, these strategic protection methods also correlate with formal IPRs. IP indicators do not correlate well with any of the other modes of innovation, suggesting that active pursuit of means of protecting innovations is a relatively specialised strategy for a sub-set of businesses.

Standards as a source of information for innovation loads together with other external information sources such as the public knowledge base, publications and other businesses to form a codified information mode, i.e. firms using explicit, written information, such as standards and publications, in their innovation activities. The use of standards shows low correlations with other modes, indicating again a relatively specialised strategy of extensive use of external information, especially in its written or codified forms.

Out of the three types of infrastructure derived knowledge considered here – (i) standards, (ii) design and (iii) IP – standards and IP have little weight in the other modes, which we term market-led or external process modernizing. The low correlation of standards with process modernizing appears surprising, as standards might be expected to include valuable information for up-grading and adapting production and business processes. Similarly, the low weight of design in the market oriented mode, which is constructed mainly of product innovation with marketing expenditures, in two waves of the innovation surveys is also perhaps surprising, although one of the elements of marketing 'hidden' in this mode is product and service redesign.

The two other types of knowledge infrastructure, measurement and accreditation, are not included as lines of questioning in the surveys, but can be represented from external sources but at a higher level of aggregation, either industrial sector or geography. These exogenous variables can be related to the summary innovation styles by means of regression analysis, that shows the extent to which the different modes of innovation are correlated with or in a sense supported by, the availability of measurement knowledge or the breadth of take up of accreditation.

The industry level variable that represents the availability of measurement related knowledge has a significant correlation with the mode of innovation that is characterised by firm level investment in the creation of intangible assets with the purpose of innovation. Measurement knowledge is partly transmitted, in the construction of this variable, through the stock of standards, so we are here also picking up the more generic role of standards as a source of innovation information.

The measurement indicator is also correlated, with the IP and technology based mode, albeit with a negative sign. This suggests that the IP mode is focussed on in-house technology, with lower degrees of access to embodied metrology, which might point to some missed opportunities for innovators to avail themselves of embodied technology, in the form of specialised, scientific and precision equipment, derived from the application of metrology.

Industry level measurement knowledge is also positively correlated with the codified knowledge mode, which emphasises information from standards and from the public knowledge base such as universities and research institutes and scientific and technical publications. This is consistent with evidence that the public research base is intertwined with the measurement system, for example through joint research and publications, (Lambert 2010) and through research and teaching institutes' use of measurement standards and expertise. This mode is also intensive in innovation relevant information from other market participants. So measurement is widely complementary to other external sources in knowledge based businesses.

Measurement knowledge is also correlated with two other innovation modes: market-led, which emphasises product innovation and investment in marketing, which probably reflects how new measurement techniques and findings, and their embodiment in standards, can enable the development of new and improved products through expanding the range of user benefits that can be incorporated in products and services; and with externally based process modernisation, which depends on external sources of expertise to supplement in-house spending on upgrading equipment and IT and on training for innovation.

In relation to accredited conformity assessment, a wide range of types and forms of accreditation are provided or managed by UKAS. Obtaining hard data on accreditation, in a form that can be used in the sort of econometric model that is at the heart of this report, is difficult. Very little statistically based analysis of accreditation has been attempted, largely due to these difficulties in obtaining systematic quantitative evidence.

In Section 5 we present some new results, based on Quality Management Standards (QMS) using ISO 9001. These are derived from data on numbers of certificates of conformity with ISO 9001 issued by most of the bodies accredited by UKAS to issue these certificates. These data have been supplied from the QA Register, which is the only available database listing awards to 9001:2008 from a range of UKAS accredited certification bodies. The data used are anonymous and the authors of this report cannot identify the businesses holding the certificates.

Because of the form in which the data are compiled, the indicator used in the analysis that follows is the share of firms by geographical area (in this case county) who hold a certificate to ISO 9001. This indicator picks up both the effects of accredited QMS certification on the business itself, but also points to possible spillover effects on other firms in the area who may be trading partners or otherwise derive benefits from encountering management practices and standards in other firms. It is important to note that ISO 9001 is a standard for good current management practices, not in itself involving testing for innovation in products, processes or in management and organisation, although it does include an element covering continuous improvement in processes. So an association between ISO 9001 and innovation indicators would be a pointer to the role of accreditation to a QMS standard as a platform for or enabler of innovation.

The ISO 9001 indicator is significantly correlated with one or more of the mixed modes of innovation, identified and estimated for the period 2006-2008. Accredited certification intensity is correlated with investment in the creation of intangible assets. It is also significantly linked with a technology based mode that involves the extensive use of IPRs, in conjunction with technology development, which implies that accredited management practices support the management of knowledge assets and the ability to exploit and protect the firm's own creation of new knowledge. QMS intensity is also significantly associated with the use of other forms of codified knowledge, including standards and the outputs of the public research based, both mediated through publications and through direct search for useful information for innovation from universities and other public research institutes.

In sum, the share of firms in an area who are certified to ISO 9001 by a UKAS accredited body shows a significant supporting role in several modes or strategic orientations of innovation. This is, we believe, a result new to the literature on innovation and its determinants while also adding a previously unavailable degree of rigour and quantification to the demonstration of the business benefits of accredited conformity, at least in the realm of QMS.

A developing area of application of the principle of accredited certification to a performance standard is in health care, and we report in the results in Section 6 on the effects of two important standards and the conformity assessment processes that support them: (i) in clinical pathology laboratories and (ii) digital imaging departments. The evidence collated there supports the conclusion that these frameworks, where UKAS provides the accreditation path and oversight, are leading to material improvements in patient service and in reduced operating costs.

A major aim of this project is to link the modes and infrastructure variables to measures of performance: productivity and growth. Some main findings from this part of the analysis are:

The mode or style of innovation termed 'codified' is based on firms using information from the public knowledge base, publications and standards, and is also supported by the exogenous variables based on measurement knowledge and ISO 9001 accreditation. That is, it reflects much of the innovation infrastructure. The codified mode is positively associated with the level of productivity and with short-term growth in turnover and employment.

The exogenous variables based on measurement knowledge and ISO 9001 accreditation also show a positive and significant contribution to performance:

- Measurement knowledge shows its impact on productivity and short-term changes in productivity, but not on short-term growth, with the implication that measurement knowledge has efficiency promoting effects in the short run, possibly including dissemination through spillover effects at industry level.

- Accreditation shows impact on productivity and growth, suggesting that sound management structures and practices, tested and approved to relevant standards, lay the foundation for good business performance and economic benefits.

The availability of panel data from the innovation survey enables the performance relationships to be investigated over time, allowing for the longer-term impacts of the infrastructure.

Sub-section 5.4 reports on equations that measure the effects of modes of innovation and the exogenous variables with a lag between the observation of performance and the innovation indicators of four to five years. Performance is observed in 2008, while the independent firm level innovation modes and the exogenous infrastructure indicators are estimated for the 2002-2004 period. Table 1 below summarises the key findings.

Table 1: Summary of findings from the econometric analysis with four year time lags

	Productivity	Change in Productivity	Change in turnover	Change in employment
Modes 2002 – 2004				
Technology/IP	***		*	
Intangibles				
Market-led				
Wider innovating			***	**
Codified knowledge	***	**	*	
External Process modernizing				
Exogenous variables				
Measurement (2004-2006)	***	***		
Accreditation (ISO 9001)	***	**	**	*

*** = significant at 1%

** = significant at 5%

* = significant at 10%

The codified knowledge mode includes standards together with the public research base, and is supported by accreditation. This mode is strongly related to the level of productivity in 2008, and also significantly correlated with change in productivity and with output growth. The technology/IP mode correlates all forms of IP, both IPRs and strategic protection methods, with R&D and a more modest weight on the use of standards. This mode is also supported by accreditation. This mode is strongly associated with the level of productivity in 2008. It is also significantly, but less strongly, associated with growth in turnover.

Wider innovating is strongly linked to growth in turnover and also moderately linked to growth in employment. The indicator of measurement knowledge intensity is linked directly to the level of productivity, i.e. in addition to its role in supporting modes of innovation. Accredited certification to ISO 9001 is, interestingly, linked to a relatively moderate extent to three growth indicators: turnover, employment and productivity, again suggesting that ratified management practices are a platform for effective expansion.

The infrastructure activities of BSI, UKAS, the NMS, and the Design Council, feed knowledge into labour productivity and growth, and have significant impact through complementarities with the public knowledge base and other forms of knowledge creation and use. Two forms of infrastructure – measurement and accredited certification to a QMS standard – also impact performance additionally to the innovation mechanism, enabling or supporting growth and productivity in their own right. These multiple routes to impact are a reminder that the infrastructure is widely specified and accessible to all firms and industries.

While building on existing studies, this report adds to our understanding of how the infrastructure institutions – BSI, NMS, IPO, UKAS, the Design Council and the varieties of knowledge they provide, have complementary and inter-locking roles and impacts in and through the system. This is the first UK based study, as far as we know, that has taken such a holistic approach to the evidence on the infrastructure and it provides part of the underpinning for the Infrastructure Initiative between BIS and the institutions concerned. The degree to which it has been possible to quantify these interdependencies is also new, as a mass of accumulated evidence from several waves of the UK Innovation Survey has been successfully integrated with indicators of the infrastructure from a variety of sources. We have thus been able to confirm and extend materially existing evidence developed for the infrastructure institutions taken individually. The main empirical and policy relevant findings include:

- The infrastructure is a key resource for the effective functioning of innovation and for economic performance more widely. Standards, design, accreditation, metrology and IP are all deeply embedded in the modes and styles of innovation practice across industry and commerce and in the public sector.

- They are complementary to, and supportive of, the other drivers of innovation, such as new technology, knowledge from the research base, organizational and managerial changes and marketing strategies.

- Notably, information from standards tends to be conjointly used with scientific and trade publications and with direct sourcing of knowledge from the research base.

- Certification to ISO 9001 by UKAS accredited bodies is positively and significantly associated with several modes of innovation and with productivity directly.

- There is a lack of systematic empirical evidence on the impact of accreditation. Although this report has used successfully an indicator for accredited management systems certification, there is a need for more research and analysis on the economic value of the accreditation system as a whole.

- The National Measurement System is part of or directly supports several types of innovation strategy and has a distinct impact on productivity.

- Design is complementary to other forma of investment in intangible assets, confirming the insights from the aggregate level innovation index project at NESTA.
- The innovation and efficiency promoting roles of the infrastructure are contributors to economic growth and productivity as well as to international competitiveness.

The analysis does though point to some areas where the relevant parts of the infrastructure, singly or severally, may be underutilized, supporting the rationale for the infrastructure initiative to explore the scope for more joint working and cross-referencing of the institution's offerings and relationships. The research set out here cannot lead to very specific proposals for action, but might suggest areas for further investigation by the institutions concerned. These include:

- Standards as a source of information do not feature strongly in the mode of innovation that emphasises process improvement and which tends to depend on external sources of information to enable the process improvements. As standards are, amongst other things, summary repositories of useable technical information, this might point to an area for further exploration.
- The overlap of standards and design in business innovation appears limited, although there is a body of standards for design management. Perhaps the design and standards worlds have some potential for exploring synergies.
- There is relatively low cross-fertilisation between IP and design, confirming the finding of Design Council surveys that the UK design industry are not themselves major users of design rights.
- More generally, the use of IP does not correlate highly with other areas of infrastructure, which may imply scope for more cross-referencing or to promoting knowledge portfolio management in businesses.
- Wider (managerial/organisational) innovation is less well correlated with QMS accredited certification, although the latter seems supportive of other types of innovation.
- Standards correlate with publications and direct information sourcing from the research base in a mode of innovation, supporting the initiatives underway to integrate research base outputs into standards making. The correlation of standards with publications suggests that published research outputs are appropriate forms of knowledge transfer of this integration, as well as direct researcher involvement.

1. Introduction

The Innovation Dynamics and Infrastructure project was established to develop and strengthen the evidence base on the patterns of business innovation over time, including the implications for economic performance. In particular it brings together and extends evidence about the role of intellectual property – both formal rights and more strategic means of protecting innovations – and the interactions of IP with the innovation infrastructure more generally. This includes the constituent institutions and the knowledge they provide, individually and jointly to business and public sector innovators. The evidence is collated and deployed in the context of the UK innovation system.

The main methodologies adopted include:

- econometric and multivariate analysis of statistical sources on innovation and its changes over time, and
- quantitative and qualitative representations of important elements of the innovation related knowledge infrastructure and how this has enabled better innovation and growth outcomes.

The study uses mixed methods, some statistical and some more qualitative in nature, depending on the type of data and indicators available. A major element has involved exploitation of the several waves of the UK Innovation Survey Data (the UK implementation of the Community Innovation Survey). The survey collects a wide range of firm level information on the innovation behaviour of several thousand UK businesses. There have now been five iterations of the survey, covering the period from 1994 to 2008, providing the opportunity to track changes over time and to link the survey data with other sources of information, which may also be at the level of the individual firm or be measured at the level of the industry or geographical locations. This element of the work aims to examine how innovation has evolved over time and explore the longer-term relationships between innovation, the knowledge infrastructure and economic performance.

The study has concentrated on the three most recent surveys – in 2005, 2007 and 2009, which provide substantial balanced panel datasets – 7,000 plus for 2005/2007 and 2007/2009, with a panel of 4,000 plus across all three surveys. The study has also built on extant bodies of research into innovation and its impacts and into some aspects of the infrastructure in innovation. The core element is a body of research under OECD auspices on modelling innovation and its impacts, including identifying innovation modes or strategies as coherent combinations of innovation inputs and outputs and using these to estimate the impact of different innovation modes of productivity and growth.

The basic models developed under the OECD project are supplemented by indicators of the knowledge stemming from innovation infrastructure, an important component of the innovation system that has previously had a lower profile in policy than more apparently dramatic interventions. The study has also taken some account of evidence on the integration of the knowledge flows from the infrastructure bodies with other parts of the publicly supported and enabled innovation system especially the research base, although it has not been possible to undertake a full scale analysis of the impact of University and other public research in the time and resources available.

The report is in six parts. Section 2 contains a brief outline of the UK innovation system. Section 3 introduces the knowledge infrastructure components investigated in this report. Section 4 introduces the data and methods used for the core empirical analysis of Section 5 which focus on exploiting the innovation survey evidence and incorporating the infrastructure indicators. Section 6 provides some case studies on the operation and impact of UKAS based accreditation.

2. The UK Innovation System

Like all modern economies, the UK economic structure and its performance in terms of growth, productivity and citizen's quality of life is underpinned by a set of economic institutions and relationships that can be usefully characterised as a National Innovation System (NIS). This section summarises important characteristics of the NIS and introduces the particular facets of the system that may be thought of as a 'knowledge infrastructure' and that are the focus of this report.

The UK innovation system is characterised through a comparatively strong research base. The UK produces world-class research, second only to the US, in terms of publications with particular strengths in many fields of sciences, humanities and social sciences. The academic research base is acknowledged as one of the best in the world, based on widely used bibliometric measures, such as numbers of publications and citations.

The innovation system is further characterised through high international integration. The UK ranks first among OECD countries in terms of its share of business expenditure on R&D financed from abroad (i.e. 23% in 2008) and around 25% of patent applications having co-inventors located abroad. Business expenditure in R&D is lower than the OECD average at about 1.6% of GDP overall, especially in medium-high tech and in medium-low and low-tech industries. At least in part this is driven by the industry composition, for example, the very high share of services in the UK (NESTA 2011).

In recent years, a range of broader models of innovation and its impact, that go beyond R&D as the primary indicator, have been developed. At aggregate level, and building on the growth accounting tradition of economic analysis, recent reports commissioned by NESTA, as part of the development of an Innovation Index, have developed the theme of innovation through intangible investment as a primary determinant of national productivity and growth (NESTA, 2010). These include investment in the development of software and databases, and economic competencies such as training and skills, organisational and brand capital, and design. These investments create sets of complementary assets for firms that jointly drive their growth and productivity.

The intangible investment analysis uses, but adapts, the standard National Accounts framework to incorporate the capital like nature of these investments, that are currently mostly treated as intermediate consumption. A range of methods have been applied to arrive at estimates of the value of these investment and to assess how far they contribute to economic growth and productivity. The approach adopted for the Innovation Index has been to estimate the values from indirect indicators, such as, for example, the volume of own account software expenditure from the numbers of software writers employed in businesses other than software houses, as revealed by employment and labour force surveys. An attempt has also been made to arrive at direct estimates of the value of intangible investment through business surveys (Awano et al., 2010). Not surprisingly, there are some differences in the investment levels indicated by these methods and work is ongoing. We do not go into detail in this report on the intangibles methodologies, but the end result of both methods is that intangibles investment in the UK is very substantial. R&D for example is only around 12% of the total. And, where internationally comparisons are possible, there is a suggestion that the share of GDP in intangibles investment may be higher in the UK than in some other major economies (NESTA 2011).

The analysis that forms the core of the present project is consistent with the intangible asset approach, in the sense of bringing out the importance of assets and capabilities complementary to technology in driving innovation and economic performance. But we use firm level micro-data instead of the aggregated investment function underlying the intangible investment model. This enables a more extensive set of firm and industry level variables to be used to characterise and quantify the component parts and linkages between them that constitute the national innovation system. A number of the micro data indicators used in this analysis – design, R&D, training, marketing – do indeed represent intangible investments at the firm level, broadly congruent with the aggregate level indicators outlined above.

Like most advanced economies, the UK has the majority of output and employment in services sectors, and shows a relatively low share of the economy in high and medium high technology manufacturing. This gives considerable importance to dimensions of innovation that are relevant to services as well as to production sectors. These can include less technologically intensive modes, including managerial and organisational changes as well as more indirect uses of technology embodied in equipment and IT.

The UK has a sophisticated, but possibly under-utilised and underfunded knowledge infrastructure, which includes a strong design industry, a highly developed standardisation and measurement system, an advanced set of institutions for IPRs, both legal and strategic, all underpinned by a framework of certification and accreditation. A deeper understanding and estimates of the impact on innovation and performance of this infrastructure is the purpose of this report.

Recent developments in empirical analysis of national innovation systems in a number of countries have suggested useful extensions to established ways of representing and quantifying innovation, such as R&D spending or counts of patents or simplifying categorisations of innovation into high-technology, low-technology and non-technological. One sort of extension, including in estimates of innovation resources a wider purview of intangible asset creation, has already been mentioned. Another, that forms the basis for this report, is to group strategies of innovation into ‘mixed modes’ which can be appropriate to firms of all sizes and in all sectors. These are described and defined more fully in a later section, but in broad terms they act as summary indicators of the strategic options pursued by firms in envisaging, developing and implementing innovation in multiple dimensions.

Within this wider context of the UK innovation system, the next section describes in more detail the UK knowledge infrastructure, including the IPR system, the national measurement system, the role of standards and accreditation and the role of the design industry.

3. The Knowledge Infrastructure

Innovation involves multiple activities, such as the use of and investment in physical and intangible assets, human capital and the introduction of new and better products and processes. It is increasingly understood that innovation can take the form of, or entail, management and organisational changes and initiatives. But the creation and dissemination of knowledge, of all types, not simply technological, is central.

Innovation-relevant knowledge has distinctive characteristics:

- Many forms of knowledge and their complex interactions are involved, from knowledge of markets to understanding of information and its management, or from how to organise a firm, to engineering and creative knowledge for design and production of goods. R&D is but one part of this complex of knowledge for innovation.

- Knowledge is produced, maintained and circulated by a diverse array of private and public organisations: the main actors in an innovation system, including businesses, universities, government departments and agencies, private sector R&D suppliers, specialised consultancies and many others. There are also infrastructural information providers and regulatory agencies (such as the Health and Safety Executive) and an important subset of these are the core of this project.

This report is concerned with the operation and impact on economic performance, through innovation and others channels, of several important sources of knowledge in the infrastructure. These are mostly codified, in the form of Intellectual Property, Standards, Accreditation, Measurement and Design. But there are also important tacit knowledge flows, through to the accumulated expertise of the staff of the institutions and their communication of this knowledge through direct contact with other economic agents. The interface between these infrastructure sources and the knowledge generated and distributed by the research base is also partially covered.

The remainder of this section briefly introduces the salient characteristics of these agencies and forms of innovation relevant knowledge and summarises extant evidence on their role in the NIS and their 'impacts' as background to the new evidence in Section 6. These infrastructure elements vary in their form and function.

3.1 The role of the IPR system

The system of Intellectual Property, that includes formal, legal rights to protection and the use, by business, of more informal or strategic mechanisms to prevent the copying or replication of their inventions and innovations, is one of the primary framework conditions for a functioning innovation system. Legal protection, such as patents, design rights, trademarks and copyright, has been enacted in individual countries and internationally, to stimulate and protect inventions and creative work. Patents for example grant a temporary monopoly in the economic exploitation of an invention, thus, in principle, providing incentives to individual and businesses both to seek and to share new useful ideas that lead to new and improved goods and services or technological possibilities.

The UK Intellectual Property Office (IPO) provides the legal institutions to protect intellectual property in the UK and aims to promote the generation and use of new ideas, designs and innovations, and enables are market for IP (e.g. using, selling, buying or licensing of IP). Thus, the IPO is an important part of the UK innovations system. Taylor Wessing Global IP Index assessed the UK's IPR system as "the most effective" based on the views of users of all types of rights, with the importance of IP and innovation expected to expand in the 21st century (Taylor and Wessing 2011).

As well as the formal system of IPRs, whose management is the main function of the IPO, businesses also use a range of strategic means to protect their innovations from replication or copying. These included confidentiality and secrecy contracts with staff, customers and suppliers; complex product designs to make replication and reverse engineering by competitors more difficult; and speed to market, to establish their products or services before competitors can introduce something identical.

3.2 The National Measurement System

The UK's National Measurement System (NMS) includes measurement and calibration labs. The measurement labs produce standards of measurement, that among other functions, facilitate trade, in particular international trade, and that are used in industry as well as governmental bodies and academia. For example, the independent accreditation and certification of UK suppliers may reduce the need of the supplier to be assessed by its customers based on a mutual recognition, at national and international level, reducing barriers to trade.

The NMS supports innovation in the way that it enables the measurement of characteristics that might be incorporated into new products and production processes. The results of measurement science research can stimulate new product development in the scientific and precision instrument and equipment sector, which then 'fans out' into use in industry, raising productivity through improved process and quality control. Measurement also underpins a wide range of public goods, including consumer protection (legal metrology), forensic science, environmental controls, safe medical treatment and food safety regulation. Accurate measurement standards underpin the technical standards that help to spread new and improved technologies through UK businesses and support international trade. Scientists from the NMS institutes are active in national and international standards committees, helping, with their expertise to make standards that economically provide knowledge to innovators.

The measurement system includes a range of complementary institutions. The National Measurement Office (NMO) provides the focus for the strategic development of the system and sets the regulatory framework. The NMS laboratories and their scientific staff maintain national measurement standards and facilities and make them available to users through knowledge transfer and a wide range of services (mostly provided on a commercial basis), and develop new measurement techniques and services in response to requirements from business and the public sector and through the application of research. These laboratories are part of the national and international science system and collaborate, for example through joint research and publication of results in scientific journals, with universities, businesses and with overseas measurement institutes.

Around 1,500 accredited calibration and testing laboratories, mainly in the private sector, and supported by an independent self-financing accreditation agency, use these standards to supply measurement services to characterise hundreds of thousands of instruments and components used in industry, trade, hospitals, universities, local government, forensics and defence. Private sector manufacturers of instrumentation and control systems (a successful high-technology exporting sector) apply the standards and expertise of the NMS laboratories to develop new equipment, for example for precision engineering and delivering accurately measured quantities or doses. This enables the quality control and assurance capabilities of private sector companies and public sector organisations who apply these instruments and control systems to the production of manufactured goods, operation of processes, delivery of services and regulatory compliance.

The national laboratories hold primary measurement standards (e.g. the standard kilogram) and they hold reference materials and equipment). The labs form the top of a calibration pyramid. They provide calibration services to a host of commercial testing laboratories. UKAS is the only national body recognised by the UK government for the accreditation of calibration and testing labs as well as other inspection and certification bodies.

Economic impacts of the UK NMS include enhanced (international) trade and manufacturing processes. Wider non-economic might include improved quality of life through better health and safety, environment standards or consumer protection. The extent to which different NMS institutions contribute to economic and non-economic outcomes will differ across the portfolio.

Empirically the impact of 'measurement intensity' on innovation has been estimated by Dr Paul Temple of the University of Surrey, using indicators of the stock of measurement knowledge and the data on product and process innovation from the UK Innovation Survey (Temple 2008, 2009). His research discovers that businesses operating in a richer measurement environment, with higher shares of the indicators that embody measurement information – the standards stock or the extent of instrument use in its industry – show a higher propensity to innovation. The effect of being in an industry with effective linkages to the NMS is particularly strong for product innovation and this relationship is consistent across two innovation surveys (Temple 2009).

3.3 The role of standards

Standards are agreed codes of best practice that improve safety, efficiency, interoperability and facilitate trade. Standards reduce costs to businesses and consumers by incorporating well defined codified information about the properties of goods, services or trading partners in a way that enables them to adopt products and processes or enter into trade with confidence.

The use of standards has also been shown to contribute to innovation in firms. Accreditation reduces bureaucracy by moderating the need for legislation; enhances efficiency by helping businesses to meet standards in efficient and cost effective ways; and engenders trust through identifying organisations that meet and maintain high standards. Together, standards and accreditation facilitate innovation in a number of ways, including: enabling higher value innovation; facilitating knowledge transfer; reducing risk/enhancing quality assurance; increasing speed to market; and helping deliver innovation in the public sector.

The British Standards Institution (BSI) and the UK Accreditation Service (UKAS) have been working together with BIS to provide information to help policy makers identify how and where standards and accreditation can be used as alternatives to regulation, enabling government to use a lighter, less burdensome touch to achieve policy objectives.

In a recent report for BIS, Peter Swann has developed an extensive analysis of the range of economic functions of standards and how these are likely to affect economic activity, productivity, innovation and consumer welfare (Swann 2010). He outlines eight fundamental types and properties of standards as follows:

- Variety reduction
- Quality and performance
- Measurement standards
- Compatibility and interoperability
- Health and safety
- Codified knowledge
- Vision

Swann notes that the overall or macro-economic effects of standards have been estimated by using the stock of active standards as an indicator that in a sense ‘rolls up’ the complexities of standards and their interaction with the economy of which they are a part. He suggests that this approach to quantifying the ‘value’ of standards (though what economists terms ‘reduced form’ models) is something of a black box, that could usefully be unpacked. The results for the way that infrastructure indicators such as standards operate in a micro-economic model of innovation and productivity, that are the core of this paper, go a little way towards that unpacking, but does not purport to address all of the ways that standards operate. The next section reports on some of the ‘reduced form’ models, which are themselves helpfully summarised in the Swann report.

While it is commonly believed that standards obstruct innovation, survey evidence suggests that standards are a source of information that helps innovation, while firms who report that standards and regulations act to constrain their innovation activities, are also more likely to innovate, so that these constraints do not prevent innovation. Innovating firms are good at finding information in standards, and also find that regulations can constrain their innovative activities, through ruling out some possible lines of development. But the information content is sufficient to enable alternative paths of development so that innovation is not prevented. (DTI 2005; Swann and Lambert 2010).

Written standards are one of the forms of codified knowledge that is readily available to business and public sector users. By setting out specifications in detail, with supporting documentation and cross referencing to sources and to related knowledge e.g. measurement results and techniques, a standard efficiently encapsulates technical or managerial information and can be used quite directly in formulating products, processes and business practices.

A report for the then DTI included three empirical studies of the role of standards in innovation, productivity and growth (DTI 2005). One was a study, using the growth in the stock of standards and of GDP over time, since 1948, which estimated that the elasticity of the growth in output with respect to increase in the net stock of standards is about 0.05. Although the elasticity itself is small, the rapid rate of growth of the stock of standards leads to an estimate that this growth contributed about 13% of the growth in labour productivity in the UK experienced over 1948-2002. In time series studies of economic and productivity growth, technological change from all sources contributed tends to contribute about one percentage point, and the study for the DTI suggests that standards growth accounts for more than a quarter of this percentage point. But it is important to note that, for technical statistical reasons, the time series model could not be estimated with both a dissemination – standards – and a new technology – e.g. patents – variable. The authors emphasise that there will in reality be interdependence between these, so that the result needs to be interpreted with appropriate care – standardisation acts in conjunction with other factors such as new technology and not independently.

A second project in the DTI report compared the macroeconomic effects of standardization in Germany, France, Italy and UK. Estimates for the elasticity of the growth in output attributable to a one percent increase in the size of the standards 'catalogue' is between 0.02 and 0.1 %. Similar studies have since been carried out for Canada (2007), Australia (2007) and France (2009), using similar methodologies (cited in Swann 2010). The empirical analysis in Canada also found that standards play an important role in enhancing labour productivity, measured as output per hour worked, accounting for 17% of the growth rate in labour productivity which translates into approximately 9% of the growth rate in real GDP. These are similar to the findings for the UK. Results in Australia were similar again, although the elasticity between the stock of standards and productivity was a little higher than the case of the UK. The French analysis found standardization contributes an average of 0.8 percentage points to growth per year, or almost 25% of GDP growth, in line with the other results cited here.

3.4 The role of accreditation

Accreditation is part of an overall system that assesses and ensures conformity with applicable requirements, focussing on providing an independent evaluation of an organisation's technical competence, thus maximising the value of standards. Accreditation reduces bureaucracy by moderating the need for legislation; enhances efficiency by helping businesses to meet standards in efficient and cost effective ways; and engenders trust through identifying organisations that meet and maintain high standards. Together, standards and accreditation facilitate innovation in a number of ways, including: enabling higher value innovation; facilitating knowledge transfer; reducing risk/enhancing quality assurance; increasing speed to market; and helping deliver innovation in the public sector.

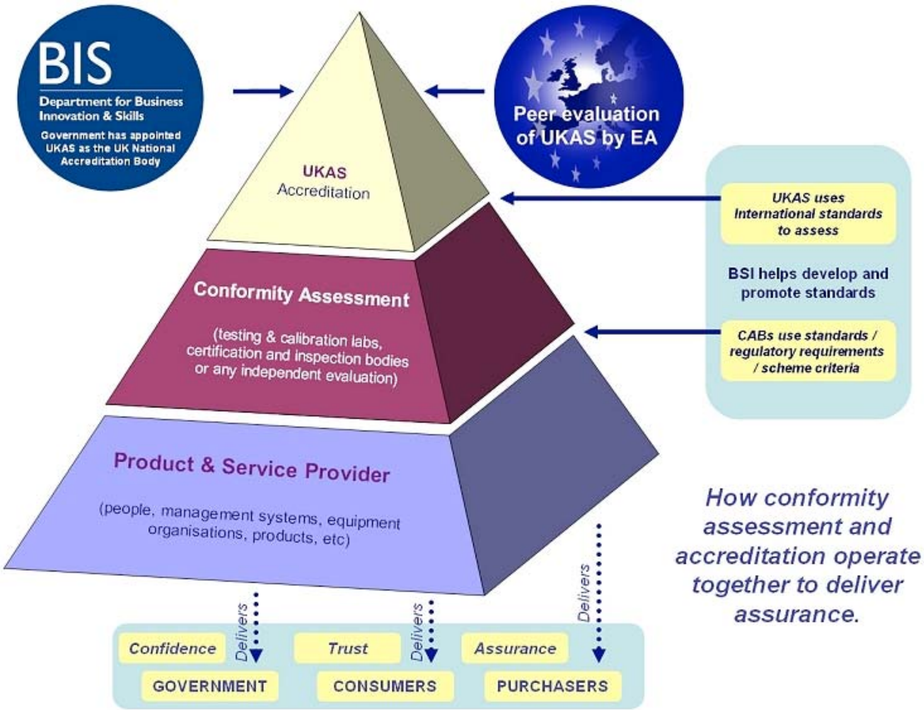
Government recognised accreditation is the responsibility of the UK's National Accreditation Body, the UK Accreditation Service (UKAS). UKAS is a non-profit-distributing private company limited by guarantee – a pioneering successful business model which may well be of utility in other areas of public sector activity. It is independent of government but is formally appointed as the national accreditation body and operates under a ‘Memorandum of Understanding’ with H.M. Government through BIS.

UKAS manages the system and is at the top of the accreditation traceability tree, as shown in Figure 3.1 below. UKAS has 180 full-time staff of whom 70% are technical, supplemented by a pool of 250 contract technical assessors. UKAS operates in most areas of the economy, with dedicated coverage of:

- Electrical, Physical and Thermal
- Imaging
- Environment
- Engineering Inspection
- Construction Materials and Mechanics
- Food, Agriculture and Bio-science
- Industrial Chemistry
- Product, personnel and management systems (including quality management) certification

Demand for accreditation has grown by 50% over the last five years, substantially in non-traditional areas, including health testing and treatment related technical services such as pathology and diagnostic imaging.

Figure 3.1 Positioning of UKAS within the wider economy



Source: UKAS, 2011.

The majority of accredited bodies and of transactions are in areas of technical testing and calibration, both for the private sector and, increasingly, in the public sector, with particular emphasis on health services, such as diagnostic imaging equipment. Accredited testing and calibration of technical equipment enables its accuracy and therefore the reliability of the services provided to be traced back to the underlying measurement standards. Users of the testing and calibration service and thus their customers can be confident that the goods and services produced using the equipment are according to specification.

The main standards for testing and calibration are:

- Laboratories in accordance with the requirements of BS EN ISO/IEC 17025:2005
- Medical Laboratories in accordance with ISO 15189
- Medical Reference Measurement Laboratories in accordance with ISO 15195

The accreditation system also covers business process standards, mostly in connection with ISO 9001 and related standards, including Environmental Management System Standards, for organisation and management. Accreditation in this field is carried out against ISO 17021. These forms of accreditation provide assurance to customers that their suppliers follow good practice in their production and supply operations, so that contracts can be entered into with confidence and at lower costs of policing and testing. QMS and related systems can also be certified by bodies not accredited by UKAS - there is a market place in certification and in accreditation. An issue for the economic and social value added of the accreditation service is the difference in impact of the certified organisations and their ultimate users, between those with and those without accreditation by UKAS. The results presented in this report draw on material from the UKAS based accreditation chain and so cannot directly address the issue of relative value.

UKAS also underpins the accreditation of professionals, whether self-employed or employed by companies, to demonstrate their adherence to technical and professional standards of competence. This aspect of accreditation has special significance where the technical aspects have significant health and safety or environmental implications. An example is the Gas Safe scheme for gas appliance fitters.

A major part of the UK accreditation system lies in the testing and calibration laboratories, that provide these specialised services across all UK sectors, for the range of equipment used in all sectors and for health and safety critical services such as asbestos testing. In itself, the technical testing sector is a significant industry that employs 43,000 people and has a turnover of nearly £6 bn. Over half of employment and nearly 75% of turnover is in 20 large businesses. The Table shows more detail on the sector.

Table 3.1 Employment in technical testing and analysis sector (SIC 712)

	Enterprises	Employees (000)	Turnover (£m)
All employers	1,990	43	5,818
Micro (1 - 9 employees)	1,575	6	464
Small (10 - 49 employees)	330	7	612
Medium (50 - 249 employees)	65	7	503
Large (250 or more employees)	20	24	4,239

Source: Authors' calculations based on IDBR data

There is considerable evidence that standards promote trade. Similarly, measurement standards, shared internationally through Mutual Recognition Agreements, also reduce non tariff barriers to international trade by reducing the costs of testing and inspection. It is less well known that accreditation is also part of the framework conditions for trade again through mutual recognition across borders of the validity of accredited certification of businesses. This effect derives again from the codified assurance that goods and services verified by accredited bodies conform to international standards, reducing the need for additional testing.

Most developed countries have an institution like UKAS. UKAS represents the UK on three international bodies: the European co-operation for Accreditation, the International Laboratory Accreditation Cooperation and the International

Accreditation Forum. This set up enables government to use accredited bodies to meet obligations under world trading agreements e.g. compliance with EU Directives and the World Trade Organisation Technical Barriers to Trade Agreement.

To support increasing export competitiveness, businesses need to demonstrate that their products meet customer requirements in international markets. This can be achieved by accredited certification and verification by formally accredited laboratories and notified bodies. For example:

- Electronic test instruments by a UK producer are used on mobile phone and in-car audio production lines in China. Calibration at a UK accredited laboratory verifies an accuracy acceptable both to the Chinese manufacturer and to designers in the USA and Germany without the need for re-evaluation in either country.

- UK-built energy-saving ventilation systems sales are growing in Europe thanks to the accredited certification of the energy efficiency of their products.

- A UK electronics manufacturer is a fast-growing world-leader in marine radar and navigational equipment thanks to accredited product certification to internationally recognised marine equipment safety standards.

- In the food industry, accreditation proved essential to the recovery of global consumer confidence in the UK red meat industry in the wake of BSE. Accreditation also underpins the main Scottish aquaculture quality schemes. But for accreditation, Scottish aquaculture would have lost the prized 'Label Rouge' listing in France.

Whilst its day-to-day accreditation work is self-financing, UKAS receives support from BIS for its international responsibilities. Due to this BIS support, both financial and in terms of BIS expertise, the UK's accreditation and certification infrastructure today leads the world and is influential internationally in the levelling of the 'playing field' of international trade.

EU Regulation (765/08) on Accreditation and Market Surveillance, which came into force on 1st of January 2010, requires acceptance of accreditation certificates and conformity assessment results across Europe irrespective of the issuing EU country of origin. This helps to enable open trade between European countries, many of them implicit rather than explicit.

International competitors, notably in the fast-growing economies of China and India, are committing substantial resource into the development of their own standards, accreditation and certification infrastructures in anticipation of benefits to their own trade. A strong UK presence in the international bodies on Accreditation helps ensure that these do not form new barriers to UK trade.

Accredited certification is generally to a national or international standard. But not all standards have a certification and accreditation framework associated with them. In principle, accreditation could be a mark of overall competence or reliability, without needing a link to a specific standard. There are certifications of equipment and processes by non accredited certifying bodies. Although in principle this provides a lower level of assurance, it is a form that will be at lower cost to the final user and so may be preferred.

3.5 The role of design

Design promotion, provided by the Design Council, is a little different from the other infrastructure elements, as it is closer to “intervention” to stimulate more or higher quality beneficial activity than that market would generate unaided. As will be seen in what follows, design in business and in the public sector is a significant ‘intangible investment’ and the role of the policy agency is essential to ensure that gaps in the take up of this intangible asset are filled through both broad and specific knowledge dissemination and transfer.

Design is an important part of innovation and economic growth. The use of design can be transformative for companies in leading or supporting product and process innovation, for managing the innovation process itself and for the commercialisation of science, and the delivery of public services.

In a recent report for BIS, Peter Swann (Swann 2010b) has extracted six essential characteristics of design, from the many variants of the concept that have been discussed by writers on the subject. These are:

- the multi-faceted character of design;
- a link from creativity to innovation;
- a source of competitive distinction;
- an approach to planning and problem-solving;
- a means of creating order out of chaos;
- an approach to systems thinking.

This multifaceted nature of design is a strength of the capability in the UK, which enables effective innovation in a range of ways that fit the needs of sectors and of the innovation process in specific businesses. Designers are part of the innovation capability of high and lower technology production industries and of the range of services sectors. Design can lead innovation through defining the characteristics of products and services that will fill users needs and values. But design is also complementary to technology and to other resources and skills, through its problem solving and ordering functions. Amending complex organisational structures, business models and processes, to improve service or increase efficiency can be aided by the systems thinking aspects of design and visualisation.

Designers are involved in product development and marketing, communications and web presence, branding and packaging. Web design is now a large part of the turnover of the industry in the UK, as design houses have diversified into web site creation (Wennberg et al 2010). The customer experience that many modern service products offer can be better provided when design skills are used to visualise and plan the product and its delivery.

Estimates of the scale of design activity in vary depending on the exact definition used. One approach, in a Design Council sponsored survey of the industry, suggests that £15 billion was spent on UK design in 2009 through in-house design teams, freelancers and specialised consultancies.

The estimate of design expenditure in the pilot NESTA index (Haskell 2009) was based on surveys such as the Annual Survey of Hours and Earning that cover those self identified as designers in sectors – architecture and engineering - not fully included in the Design Council survey categories. This suggests that design investment through these groups of activities amounts to around £20 bn, which can be compared with £15 bn on formal R&D activities by business.

As a further development of the intangible assets approach, as part of the NESTA Index project, Imperial College and ONS have surveyed businesses on their intangible investment (Awano et al 2011). This has led to rather lower estimates of design investment in intangible asset formation. These differences reflect the multiplicity of forms and applications of design and therefore alternative practical definitions when carrying out empirical work.

As noted above, there are a number of ways of defining and measuring the UK Design sector. The results of a Design Council sponsored survey of both design consultancies and design units within other companies was quoted. Another approach makes use of ‘official statistics’ though the classification of industry and commerce through the Standard Industrial Classification system (SIC). The system, as revised recently, enables the identification and quantification of a number of Design categories, including Specialised Designers, Web Design and Engineering Design. The approximate turnovers are: Website Design: = £2.2 bn; Engineering Design = £6.4 bn; Specialist Design = £3.5 bn; Total - £12.1 bn. This estimate is reasonably close to that derived from the Design Council Survey.

Another perspective on design and its impacts can be derived from the regular UK Innovation Survey. The survey questionnaire requires that design expenditure carried out as part of Research and Development be included under that head, rather than under design. The survey excludes businesses with less than 10 employees and all of the public sector. Only around 20% of respondent report direct design activity in their product and process innovation, with expenditure of around £1.7 bn.

There remain some areas of business, the public sector and innovation practice, where the potential of design and sourcing of expertise and creative direction from the design industry is underdeveloped. The gaps in utilisation are more in the extent of strategic and leadership roles allotted to design and the design industry as a supplier, than in awareness and utilisation of design at some less advanced levels. Design is also more widely used in the marketing stage of the innovation process than as part of research or new product and process development. This gap gives rise to the potential for a national design body to provide a knowledge distribution hub that can promote and embed design as a strategic component of innovation and competitiveness. The Design Council is the main UK Design Policy body, although it is also part of an extensive network of representative bodies, both national and local. The Council both advises Government on policy towards design and itself undertakes or manages interventions aimed at promoting the use of design expertise or good design principles across the private and public sectors. Recent ‘flagship’ activities include:

Designing Demand – a support programme that provides a matching service and some degree of financial subsidy, for small firms to engage with specialised design consultancies to enhance their innovation and competitive capabilities. Economic evaluations have supported the role of Designing Demand in stimulating the take up of design as a strategic part of business in many SMES leading to commercial benefits to the firms and thus to competitiveness with a net positive effect on regional and national GVA and on job creation.

Design in the public sector with emphasis on healthcare: ‘Design Bugs Out’, for example, has helped to developed improved hospital beds and furniture that are easier to keep clean and can be more flexibly deployed.

In pursuit of its role as a knowledge hub for the spread of good design practices, the Council's website is a valuable source for designers and design users all over the world. Visitors to the website have utilised several different pages of advice and good practice guidance and have downloaded more detailed guides to good design management and practice, prepared by Design Council Staff. A rough indication of the economic value of these guides is the cost in fees and time needed to procure training roughly equivalent to the information in the Guide, which is around £450 per day. Although this is an upper bound - face to face training would add value through the tacit knowledge imparted by a teacher - it does suggest that the web presence of the Council is highly valued by designers and users, so that the role of broader spectrum design knowledge diffusion is fulfilled.

This section described, and discussed existing empirical evidence on the infrastructure bodies of the UK innovation system. This rest of the report explores their joint roles in innovation and performance.

4. Data and methodology

One of the starting points for the analysis in this report is a recent project under OECD auspices, using the micro-data from innovation surveys across 18 countries, to develop analytical and econometric models of how innovation operate in terms of the behaviours of businesses and their systemic connections, including with the public research base. The contributions of the OECD level work lie in (a) the identification of 'core' innovation modes that are found – in varying connotations – in (almost) all countries; (b) examining – via regression analysis – the role that different innovation modes play in firm performance and growth; and (c) analysing the extent to which there is convergence of modes within selected sectors across countries. Through the ability offered by the survey data to model external linkages together with firm level innovation behaviours, this research can jointly characterise and quantify the individual and national innovation eco-systems.

Five core modes of innovation, broadly similar across countries, though with significant national variations, emerge from the analysis:

1. IP/technology innovating – largely representing use of in-house R&D, and formal appropriation methods i.e. Intellectual Property Rights.

2. Marketing based innovating – this broadly combines new-to-firm product innovation with investment or initiatives in the distribution and marketing of innovations

3. Process modernising is characterised by the introduction of a new process, together with buying in of machinery, equipment or IT, and external (supplier) contributions to the innovation mode.

4. Wider innovating links together managerial and organisational innovations.

5. Networked innovating links internal R&D with bought in R&D, closeness to the knowledge base and cooperation on innovation.

This work can be used to compare differences in innovation modes across broad industry groups within a country, and to some extent look at similarities and differences in innovation modes in industries across countries

The first new contribution of this report is to extend the innovation modes model to a wider range of variables from the UK Innovation Survey. The new version generates 6 slightly different modes but related to those from the OECD project. The second contribution is to take account more explicitly than before of the innovation infrastructure as described in the preceding section and, to the extent that the available information and data permit, of the cross linkages and interdependencies between the types of knowledge that the infrastructure provides and with the other determinants and effects of innovation. This section introduces the methodologies and empirical data used to explore the role of the wider innovation infrastructure, its interplay with the knowledge base and business innovation.

4.1 Wider methodology: a mix of survey and case study strategy

The main sources of evidence are the UK Innovation Surveys. The survey evidence is further complemented with case studies, reported in Section 6. These include a number of Health care sector examples and the effect of accredited certification of technical standards in asbestos removal on the market for insurance of specialized laboratories that are accredited via UKAS.

On the modelling side – the quantitative empirical evidence – we build on the OECD project (OECD 2009) and use the following two-step method already tested in the setting of 18 OECD countries. First, we develop innovation modes through exploratory factor analyses of the innovation survey data. Innovation modes, introduced in the previous section, are bundles of activities undertaken jointly by firms to bring about new developments in products and processes as well as in operating efficiency. Second, we use dynamic regressions to examine the relative impact of innovation modes as well as additional infrastructure variables and a set of control variables on indicators of firms' labour productivity and growth.

Innovation modes – sometimes called routines or strategies - capture bundles of innovation related activities that form complements and are done jointly by firms. An example is the innovation mode 'process modernizing' in which the following activities are pursued together: firms introducing a new process, and purchase new machinery and equipment for the new process, while at the same time reporting expenditures on training of staff to implement the new process. Typically, these three activities form one distinct innovation mode, and, on average, correlate across a large range of innovation surveys (OECD 2009).

The methodology employed to develop the innovation modes is exploratory factor analysis. Since innovation survey data have been widely available to researchers, this methodology has become well established (e.g. OECD 2009, Battisti and Stoneman 2010, Hollenstein 2003, Leiponen and Drejer 2007).

This way of 'letting the data speak' has the following advantages for our project. First, it requires less behavioural assumption about the activities that hang together. Second, factor analysis reveals the dimensionality of key concepts as well as complementarities between activities. Third, the saved factor scores can be used as variables in regression model. This avoids problems caused by bivariate correlations, which are high in a study that considers a large number of variables. This project aims at systematically analysing a very large breadth of variables. A final advantage is that the factor analysis informs us about the number of relevant innovation modes based on the amount of variability in the data that each mode explains.

The variables feeding into the analysis include what sequential approaches might term inputs into and outputs of the innovation process, e.g. in-house R&D and product innovation, activities referred to as non-technological, e.g. managerial changes or new marketing concepts; and knowledge sources, which might be internal like R&D, acquired from external sources, such as Universities, or generated in collaboration with others. Importantly, a range of firm level infrastructure variables introduced in the next section feed directly into the innovation modes.

The results of the factor analyses are saved as factor scores. These factor scores form variables that allocate a value to each firm explaining whether or not an individual enterprise was high or low on an innovation mode. The factor scores are then used as independent variables in dynamic regressions that predict labour productivity and changes in productivity (while controlling for productivity levels in the pervious periods as well as a set of control variables).

The regressions also include among the independent variables industry and regional measures that are indicative of the relevance of wider infrastructure, such as the stock of standards available to a specific sector. The next section explains how we quantify the innovation infrastructure for the purpose of this report. This is followed by an overview of the specific variables feeding into the factor analyses and regressions.

4.2 The UK Innovation Survey

The main source of empirical data analysed in this report is the UK Innovation Survey. This survey collects a wide range of firm level information on the innovation behaviour of several thousand UK businesses. The unit of analysis is the enterprise. The survey covers manufacturing, and most private services. Surveys are representative across 2-digit industry sectors, UK regions and across different size bands of enterprises with 10 or more employees.

There have now been five iterations of the survey, covering the period from 1994 to 2008, providing the opportunity to track changes over time and to link the survey data with other sources of information, which may also be at the level of the individual firm or be measured at the level of the industry or geographical areas.

This study concentrates on the three most recent surveys, UKIS2005, 2007 and 2009, which provide a substantial balanced panel datasets: 7,000 plus observations for the two wave panels UKIS2005 and2007 as well as UKIS2007 and 2009; and 4,000 plus across all three waves UKIS2005, 2007 and 2009.

The following section discusses how we measure the wider innovation infrastructure: by a) highlighting areas of the innovation surveys that are used and b) information that is collected externally to the surveys and is linked / merged into the surveys at the level of the industry.

4.3 Mapping and quantifying the innovation infrastructure

The empirical work includes indicators of the knowledge stemming from innovation infrastructure, an important component of the innovation system that has previously had a lower profile in policy than more apparently dramatic interventions. The study also takes account of evidence on the integration of the knowledge flows from the infrastructure bodies with other parts of publicly supported and enabled innovation system especially the research base.

The areas that are of central importance to this report are: (i) the use of standards, and, linked with this, the effects of accreditation, with metrology and the measurement system, (ii) the Intellectual Property Rights (IPR) system and the interplay of IPRs with alternative protection methods such as secrecy; (iii) the role of firms' internal design activities and the role of the design sector; and (iv) the role of the knowledge base.

These dimensions/areas are considered at the level of the firm and the level of the industry or geography. For example, we use the innovation surveys to capture firms' internal design expenditures and the use of registered designs. We use data aggregated at industry level to measure the take up of external design services. This information is taken from a survey carried out by the Design Council. The firm level variables are internal to the innovation surveys, but the industry level variables are external and exogenous information that is merged with the innovation surveys. The following describes the measures feeding into the report.

The area of standards, measurement and accreditation is the least understood area, and comparatively more effort is placed in this report to quantify related activities, especially on accreditation where there is a singular lack of previous analysis. The importance of standards in business innovation and performance is discussed in Blind (2004) and Swann (2010). In particular with respect to the measurement system and accreditation services little empirical work has been carried out. One notable exception is the work by Temple (2008, 2009) who empirically explores the role of the measurement system (see also Lambert 2010).

The innovation surveys include information on the use of industry, technical or service standards as information for innovation. At the industry level we use a variable that measures the stock of standards relevant to an industry and that industry's purchases of instruments, the combination of which acts as a proxy for measurement. There are 97 industry groups identified in the variable. The variable is directly taken from the work done by Temple (2008, 2009). The variable is based on the following two data sources: (a) the count of standards derived from the British Standard Institute (BSI) for the years 1999, 2003, 2005 (mid-points of the reference periods) and (b) the Office for National Statistics 'Supply and Use Tables' (based on 123 product categories). The latter was informed by the National Physical Laboratory's (NPL) customer survey that identified the purchases of scientific and precision instruments as a major channel by which the services of the NPL feed into industry.

To cover some aspects of the accreditation system, we include a measure relating to the accredited certification of management standards, i.e. the ISO 9001 family. This variable is aggregated at the geographical level. It is the number of accredited certifications within an area normalized by the number of enterprises in the area. This variable is merged with the UKIS via the locational information. There are 55 geographical regions identified by the variable. These data have been supplied from the QA Register, which is the only available database listing awards to ISO 9001 from a range of UKAS accredited certification bodies. An advantage of this indicator is that management standards are relevant to all types of businesses and sectors (while some of the technical standards are relevant to specific sectors only).

IPRs and alternative protection methods are measured at the firm level through a set of questionnaire items. These questionnaire items ask the enterprise if they used the following legal protection methods: patents, copyrights and registered design. The survey also covers strategic protection methods including: secrecy, lead-time advantage and complexity of design, and these are also used. The variables are self-assessed by the enterprise, and provide a comprehensive cover of the key IPRs and alternative protection methods. Data at the industry level is available through the UK Intellectual Property Office in the form of the stock of patents, trademarks, and registered designs within a specific industry group. While such data provide exogenous measures of the relevance of IPRs across sectors, including it is beyond the scope of the current project, but might open avenues for future research.

The innovation surveys contain information about expenditures on ‘all forms of design’ (excluding expenditures on R&D which is covered in a separate question). Further, and linked to the role of design, are two questions already discussed above: (i) the use of registered designs to protect the aesthetics and looks of a product; (ii) and the complexity of design that acts as a protection from imitation of innovations by others. Bruce Tether (Tether 2005) suggests that innovation survey data currently under-estimates design activities due in part caused by a lack of an established guide to measurement of ‘design’. By contrast the concept of R&D is comparatively well defined. Tether further explores ‘hidden design’: at one end of the spectrum design is part of the development process of goods and services and overlaps with in-house R&D; on the other end of the spectrum it is linked to the aesthetics and looks of products and marketing activities. Both R&D and marketing are captured by the innovation surveys and the relevant questions are included in this project.

We merge the innovation surveys with industry level data that captures the expenditures on design consultancies by firms in a specific industry. The data source is the Design Council’s National Survey of Firms. This survey provides partial information: the industry of the main customers of the design industry and the expenditure of in-house design teams. This can be disaggregated to around 40 industries – the majority in manufacturing – using some strong assumptions to substitute for the many missing values. This provides an exogenous variable that captures the intensity of design use within a broad sector.

The role of the knowledge base is fairly well captured within the innovation surveys. The surveys include questions on the use and importance of information from universities and from public and private research organizations. The surveys also include a variable that captures collaboration with research organizations. Furthermore, enterprises are asked about the importance of scientific journals and the trade/technical press as a source of information for innovation activities. This variable is included as a codified output of the research base. At the industry level possible variables relate to the stock of scientific publications by industry. Such variables might be constructed from databases including the Web of Science. The information is not readily available, and compiling a relevant database at the industry level lies outside the scope of this particular project. Thus, relevant types of measures are included in the conceptual discussions in the report, but not included in the empirical part of the project.

4.4 The variables

This section provides an overview of (i) the variables feeding into the innovation modes; (ii) the variables exogenous to the innovation surveys; (iii) indicators of firm performance; and (iv) a set of control variables used in the estimations. Table 4.1 below sets out the variables that feed into the innovation modes. Tables 4.2 and 4.3 summarise additional variables used in the regressions.

Table 4.1 Variables feeding into the innovation modes

Variable Name		Variable Description
1	Product innovation	Enterprise introduced a good or service only new to the firm
2	Process innovation	Enterprise introduced a new process
3	New-to-market	Enterprise introduced a new product or process that was new to the market
4	Strategy	Enterprise introduced corporate strategy
5	Management	Enterprise introduced new management technique
6	Structure	Enterprise introduced a new organizational structure
7	Marketing strategy	Enterprise introduced a new marketing strategy
8	In-house R&D	Enterprise carried out in-house R&D
9	Sourcing	Enterprise bought in R&D or other knowledge, e.g. licensing-in
10	Machinery	Enterprise bought new machinery
11	Training	Enterprise had expenditures related to training for innovation processes
12	Design expenditure	Enterprise spent on design activities
13	Marketing expenditure	Enterprise spent on market launch of new goods or services
14	External innovating	New goods, services or processes were mainly developed externally
15	Cooperation	Enterprise cooperated on innovation with external partner
16	Information markets	Medium or high importance of information from other businesses

Variable Name		Variable Description
17	Info. knowledge base	Medium or high importance of universities and research organisations
18	Standards	Medium or high importance of technical, industry and service standards
19	Publications	Medium or high importance of scientific journals and technical publications
20	Patents	Use of patents
21	Design right	Use of registered designs
22	Copyright	Use of copyrights
23	Secrecy	Use of secrecy
24	Design complexity	Use of complexity of design
25	Lead time advantage	Use of lead-time advantage

All variables in Table 4.1 are binary variables taking values of one if an enterprise engaged in the relevant activity and zero otherwise. In the selection of variables feeding into the innovation modes our aim was to consider a comprehensive range of innovation activities, including activities leaning towards the technological end, such as in-house R&D and to the non-technological end of the spectrum, such as the introduction of new management techniques. We also include what might be referred to as inputs (e.g. engaging in R&D) and outputs (e.g. introducing a new product) into the innovation process. Such a distinction between inputs and outputs is based on a sequential view of the innovation process and assumes a degree of demarcation between activities that feed into innovation and introducing a new or improved production process or product. We suggest that there is considerable overlap and blurred boundaries around inputs and outputs that lead them to be jointly determined, and the majority of studies on innovation modes consider both so called inputs and outputs together.

Of particular interest, and, novel to this report, is the inclusion of the following variables: design expenditures; importance of technical, industry or service standards as information for innovation; secrecy; design complexity; and lead-time advantage as protection methods. Of specific interest is also the variable capturing the importance of information from the knowledge base, i.e. universities and other research institutes, importance of scientific journal and trade/technical publications, and the use of formal IPRs. The modes reveal the complementarities between these variables and between these variables and other innovation related activities.

The innovation modes are linked with three exogenous variables that capture different dimensions of the wider infrastructure: (i) a variable that captures the relative extent of measurement related knowledge in an industry, termed here “combined score” following the terminology of by Temple (2008, 2009) who created this indicator; (ii) the stock of accredited certificates of conformity with the management standard ISO 9001; (iii) the expenditures on design consultancies within an industry. Table 4.2 gives an overview:

Table 4.2 Infrastructure variables at industry or geographical level

Variable Name		Variable Description
1	Combined score	Combined quartile: the stock of standards and purchases of instruments of the enterprise’s industry.
2	ISO 9001	Number of ISO 9001 certificates within the geographical area of an enterprise
3	Design consultancy	Expenditures in £000s of the enterprise’s industry.

The variable combined score developed by Temple (2009) takes values from zero to six. Each industry is given a value of zero to three on the two dimensions of: stock of standards in an industry and purchases of scientific instruments in the industry. The values zero to three identify the quartile where the industry lies. Combined score is the sum of the two quartile allocations. If an enterprise’s industry is in the upper quartile for both dimensions the allocated value is six; and if an enterprise’s industry is in the lower quartile on both dimension the value of combined score is zero.

The variable ISO 9001 is the stock of accredited QMS certificates within the enterprise’s geographical area normalized by the number of enterprises within the area. And the variable design consultancy is the amount spent on design consultancies by the industry of the enterprise.

The innovation modes, plus the three infrastructure variables, are used in regressions to predict enterprise level performance. The variables that we use to measure performance are taken from the innovation surveys. They are summarised in Table 4.3.

Table 4.3 Dependent variables used in the regressions

Variable Name		Variable Description
1	Productivity 2008	Log of turnover 2008 - log of employment 2008
2	Productivity 2006	Log of turnover 2006 - log of employment 2006
3	Change in productivity 2006-8	Productivity 2008 - productivity 2006
4	Change in productivity 2004-6	Productivity 2006 - productivity 2004
5	Change in turnover 2006-8	Log turnover 2008 - log turnover 2006
6	Change in turnover 2006-8	Log turnover 2006 - log turnover 2004
7	Change in employment 2006-8	Log employment 2008 - log employment 2006
8	Change in employment 2004-6	Log employment 2006 - log employment 2004

In the regressions we examine the relative effect of innovation modes on basic measures of labour productivity (log of turnover per employee), as well as change in productivity, turnover and employment. We consider these variables for the years 2008, taken from UK IS2009, as well as 2006, taken from UK IS2007. The latter is included because the financial crisis of 2008 could impact on our estimates based on the later survey data.

The key independent variables used in the regressions are measures of the innovation modes derived through factor analysing the variables listed in Table 4.1. We also include a set of customary control variables in the regressions that are listed in Table 4.4 below.

Table 4.4 Control variables used in the regressions

Variable Name		Variable Description
1	Skills	Log of the share of graduates, including in science and engineering
2	International markets	Enterprise operated in international markets
3	Employment	Log of number of employees
4	Industry dummies	2-digit industry dummies

4.5 Methods: factor analysis and regressions

Factor analysis is applied to the variables listed in Table 4.1 to derive modes or practices of innovation. The technique reduces the set of variables to underlying concepts (factors) which summarise combinations of activities. In other words, we discover which measures form coherent subsets. The variables of a subset/factor are correlated with one another. The strength of their correlations with a specific mode is summarised in factor loadings. It is an important aspect of this technique that the analyst gives an interpretative label to the factor that responds to the sub-set of variables that most determine it.

All variables feeding into the factor analysis are measured on a binary scale. Binary data factor analysis involves the computation of a tetrachoric correlation matrix, and factor analysing this matrix, under the assumption that the observed binary variables correspond to latent continuous variables (e.g. Battisti and Stoneman 2010, OECD 2009). The number of innovation modes/factors that are retained is determined by the data. A six factor solutions is reported and applied and this corresponds with the number of factors that have Eigenvalues greater than one, the usual cut-off point in factor analysis.

The factor analyses are based on firms that were innovation active. An innovation active enterprise either had a new or improved product (goods or services), a new or improved process, or abandoned or ongoing innovation projects. Non-innovation active firms do not feed into the factor analyses for two reasons: (a) because non-innovation active enterprises skipped relevant parts of the questionnaire due to filter questions; and (b) including them leads to a one factor solution separating innovation active from non-active enterprises.

The resulting innovation mode variables are the saved factor scores using the regression approach to estimating factor scores. These factor scores are estimates of how an enterprise scores on any of the innovation modes/practices and have a mean of zero and a standard deviation of one. Under the assumption of normal distribution this means that the interval -1 to 1 contains approximately 68% of enterprises, and the interval -2 to 2 around 95%. A positive score on this variable suggests a relative specialisation of an enterprise within the mode. Enterprises might use more than one innovation mode.

We carry out two sets of regressions. First, we regress the modes on the meso-level infrastructure variables. This is done to see if stocks of standards and certifications or the uptake of design consultancies have a positive impact on some or all of the innovation practices applied by firms. Second, we examine the impact of innovation modes and infrastructure variables on firm performance. The performance measures are: (firm's own) labour productivity, change in labour productivity and employment and turnover growth.

All estimations are by ordinary least squares with robust standard errors. The regressions are computed with and without time lags between explanatory variables and outcome variables. The time lags address, at least to some extent, possible issues of endogeneity, where for example, growth in a period might spur a specific innovation modality. The following datasets are explored: (i) where the regressions are without time lags, we use the full sample (all innovation active and non-active) enterprises that responded to the UKIS2009 (around 16,000 observations); (ii) when we use the first (shortest) time lag we analyse the 9,000 enterprises that responded to both UKIS2007 and 2009; (iii) to explore the longer time lag between innovation and performance we use the panel between UKIS2005, 2007 and 2009 (around 4,000 observations). Using the balanced panel between two or three waves of the surveys leads to a bias in the datasets towards larger and more established firms. This in turn might lead to an over-reporting of innovation activity within these data, making the results less useful when benchmarking the number of innovating firms overtime. However, it is possible to compare the relative importance of different modes vis-à-vis one another, which is the key aim of the report.

5. Results of the quantitative empirical analysis

The results section is divided into three parts. Sub-section 5.1 introduces the innovation modes, and compares modes across the three waves of the innovation survey: UKIS2009, 2007 and 2005. Sub-section 5.2 explores the link between industry and regional level variables on standards/measurement, certification and design and the innovation modes. Finally, Sub-section 5.3 examines the effects of innovation modes and infrastructure variables on enterprise performance indicators.

5.1 Results: mixed modes of innovation

This section explores the results of the factor analyses and introduces the innovation modes. There are three factor analyses: (i) based on UKIS2009; (ii) based on the overlap between UKIS2007 and 2009; and (iii) based on the overlap between UKIS2005, 2007 and 2009. It is the results of these three factor analyses that later, in Sub-sections 5.2 and 5.3 feed into the regressions using different time lags between performance and innovation practices.

The individual variables, listed in Table 5.1, and taken from the UKIS2009, are on the left hand side of Table 5.1. They determine the rows of the table. Across the top are the six innovation modes. The numbers in the individual cells are correlation coefficients of a specific variable with a specific mode (e.g. cell 1 – the correlation between product innovation and IP/technology innovating is r=0.23). The correlations are referred to as factor loadings. Correlations above 0.5 and below -0.5 are strong correlations. These are highlighted in the table in pink. Moderate correlations are between 0.3 and 0.5 (and -0.3 and -0.5) and are highlighted in green. Our interpretation and naming of the innovation modes is based on these correlations/factor loadings with most reliance on the strong correlations (pink factor loadings). The factor analysis reveals six distinctive mixed modes.

Table 5.1 Mixed modes of innovation. Reference period is the three year period 2006 to 2008. Dataset is the UKIS2009.

	IP/techn. innovating	Investing in intangibles	Using codified knowledge	Wider innovating	Market-led innovating	External process modernizing
Product innovation	0.23	0.13	-0.01	0.14	0.92	0.14
Process innovation	0.21	0.23	0.08	0.19	-0.73	0.41
New-to-market	0.46	0.31	0.06	0.10	0.43	0.41
Strategy	0.12	0.11	0.10	0.85	0.02	-0.02

	IP/techn. innovating	Investing in intangibles	Using codified knowledge	Wider innovating	Market-led innovating	External process modernizing
Management	0.12	0.13	0.14	0.71	-0.12	0.05
Structure	0.07	0.09	0.15	0.81	0.00	-0.03
Marketing strategy	0.00	0.23	0.06	0.74	0.23	0.09
In-house R&D	0.49	0.66	0.13	0.08	0.09	-0.31
Sourcing	0.26	0.60	0.16	0.15	-0.05	-0.08
Machinery	0.02	0.80	0.12	0.08	-0.09	0.09
Training	0.05	0.81	0.14	0.18	-0.05	0.15
Design expenditure	0.41	0.64	0.09	0.08	0.12	-0.13
Marketing expenditure	0.31	0.66	0.12	0.18	0.35	-0.07
External innovating	-0.05	-0.05	0.04	0.00	0.00	0.90
Cooperation	0.38	0.17	0.50	0.12	-0.14	0.04
Information markets	0.21	0.05	0.84	0.12	-0.05	0.04
Info. knowledge base	0.21	0.20	0.68	0.15	-0.08	-0.03
Standards	0.02	0.12	0.83	0.12	0.02	-0.03
Publications	0.09	0.15	0.81	0.04	0.06	0.07
Patents	0.86	0.12	0.19	0.01	0.00	-0.03
Registered design	0.85	0.17	0.14	0.11	0.08	0.02
Copyright	0.70	0.20	0.10	0.16	0.13	0.04

Source: UKIS2009. Innovation active firms only. N=2,743. Rotated factor matrix of a tetrachoric correlation matrix. Rotation method is oblimin (0.5). Six factors with Eigenvalues greater than one are retained.

Factor 1, entitled IP/technology innovating, is characterised by a high loading of the IPR variables (use of patents, registered designs and copyrights). New-to-market product innovation, in-house R&D and design expenditure also load up on this factor. In the UKIS2009 no information on alternative, strategic protection methods is available, but they are included in the two previous waves of the survey, where they also load up on the IP/technology innovating mode. This mode has a natural interpretation as a strategy of in-house technology development. More discussion around this follows below in connection with Tables 5.2 and 5.3.

The second factor, investing in intangibles, takes its highest loading from the investment in human capital via the training of staff in connection with innovation. Training hangs together with the purchasing of new equipment and machinery, including computer hardware and software. Investing in intangibles also includes expenditures on traditional R&D activities, in-house or bought in (sourcing), and on design and marketing. This appears as a strategy of developing the knowledge base of the enterprise.

We name Factor 3 as using codified knowledge, because of the high loading on the importance of information for innovation from scientific and technical publications and formal standards. This mode places emphasis on applied and generic knowledge derived from other firms, universities and research organisations. This innovation mode directly captures the role of standards in firm-level innovation practices and we can trace through it the role of standards in firm performance (see Sub-section 5.3). Cooperation also loads up strongly on this innovation mode, suggesting that some element of codified knowledge is important when firms cooperate on innovation activities to facilitate the exchange across firm boundaries.

Factor 4 is wider innovating that joins organisational and managerial innovations with new marketing strategies. This innovation mode is particularly non-technological, but reflects the increasingly recognised importance of organisational change in innovation broadly conceived. We might expect this mode to correlate with the variable that summarises the stock of ISO 9001 certificates in a county (see Sub-section 5.2).

Factor 5, market-led innovating, takes its name from the high loading of expenditures on the market launch of new products (goods and services). This might be to do with a push of new improvements onto the market. The factor loads with both indicators of product innovation and has a negative loading with process innovation. This strategy can be seen as very focussed on the market place.

Factor 6, external process innovation, is so called, due to the high loadings of process innovation that at the same time are substantially enabled by resources acquired form outside the firm (i.e. a high loading of external innovating). In-house R&D has a moderate, negative correlation with this mode.

Tables 5.2 and 5.3 repeat the factor analysis presented in Table 5.1 with the following differences: (i) the reference periods are earlier periods – 2004 to 2006 and 2002 to 2004; (ii) because the additional factor analyses are based on earlier waves of the survey, and variables measuring strategic protection methods over and above formal IPRs are available in these surveys, an additional three variables feed into the modes. Tables 5.2 and 5.3 are the two additional factor analyses based on which the innovation modes variables are calculated that we use in firm performance regressions with time lags in Sub-section 5.3.

Table 5.2 Mixed modes of innovation. Reference period is the three year period 2004 to 2006. Dataset is the balanced panel between IS2007 and 2009.

	IP/techn. innovating	Investing in intangibles	Using codified knowledge	Wider innovating	Market-led innovating	External process modernizing
Product innovation	0.05	0.02	0.10	0.12	0.92	-0.14
Process innovation	0.05	0.08	0.06	0.15	-0.14	0.80
New-to-market	0.36	0.23	-0.11	0.09	0.71	0.25
Strategy	0.08	0.10	0.07	0.84	0.08	0.06
Management	0.13	0.08	0.13	0.73	-0.04	0.12
Structure	0.16	0.06	0.11	0.83	0.01	0.10
Marketing strategy	0.03	0.12	0.08	0.78	0.21	-0.02
In-house R&D	0.35	0.77	0.09	0.06	0.03	0.13
Sourcing	0.22	0.40	0.26	0.16	0.12	0.44
Machinery	-0.01	0.45	0.44	0.11	0.00	0.37
Training	0.05	0.43	0.49	0.22	0.16	0.37
Design expenditure	0.29	0.68	0.18	0.09	0.16	0.17
Marketing expenditure	0.20	0.60	0.25	0.37	0.29	0.03
External innovating	-0.26	-0.59	0.20	-0.15	0.15	0.37
Cooperation	0.24	0.24	-0.04	0.14	0.17	0.50
Information markets	0.29	0.27	0.69	0.23	0.01	0.10
Info. knowledge base	0.33	0.11	0.51	0.20	0.02	0.27
Standards	0.32	-0.01	0.76	0.16	0.00	0.03
Publications	0.31	0.04	0.72	-0.01	0.06	-0.11
Patents	0.90	0.03	0.07	0.01	0.04	0.06
Registered design	0.88	0.09	0.12	0.07	0.04	0.00
Copyright	0.84	0.05	0.15	0.09	0.10	0.04
Secrecy	0.77	0.16	0.17	0.11	0.03	0.07
Design complexity	0.78	0.27	0.08	0.06	0.10	-0.03
Lead time advantage	0.70	0.23	0.18	0.12	0.01	-0.01

Source: Balanced panel between UKIS2007 and 2009.

Notes: Innovation active firms only. N=1,827. Rotated factor matrix of a tetrachoric correlation matrix. Rotation method is oblimin (0.5). Six factors with Eigenvalues greater than one are retained.

Table 5.3 Mixed modes of innovation. Reference period is the three year period 2002 to 2004. Dataset is the balanced panel between IS2005, 2007 and 2009

	IP/techn. innovating	Investing in intangibles	Using codified knowledge	Wider innovating	Market-led innovating	External process modernizing
Product innovation	0.27	0.07	0.06	-0.14	0.81	0.24
Process innovation	0.08	0.36	0.01	0.08	0.28	0.63
New-to-market	0.36	0.08	0.01	-0.02	0.79	0.18
Strategy	0.04	-0.05	0.09	0.82	0.06	0.03
Management	0.00	0.19	0.10	0.65	-0.14	-0.22
Structure	0.20	0.06	0.02	0.73	-0.11	-0.05
Marketing strategy	0.15	0.09	0.04	0.67	0.11	-0.07
In-house R&D	0.42	0.41	-0.02	0.05	0.53	-0.20
Sourcing	0.18	0.55	0.26	0.04	0.35	-0.18
Machinery	0.13	0.84	0.05	0.00	0.03	0.29
Training	0.12	0.80	0.14	0.08	0.11	0.01
Design expenditure	0.35	0.49	0.01	0.06	0.46	-0.27
Marketing expenditure	0.29	0.45	0.05	0.18	0.49	-0.19
External innovating	-0.26	0.07	0.11	-0.22	0.14	0.77
Cooperation	0.04	0.19	0.32	0.16	0.58	-0.01
Information markets	0.36	0.49	0.49	0.05	0.16	0.17
Info. knowledge base	0.25	0.28	0.61	0.08	0.20	-0.08
Standards	0.32	0.16	0.73	0.07	-0.07	-0.01
Publications	0.23	0.01	0.80	0.07	0.09	0.12
Patents	0.84	0.03	0.15	-0.03	0.17	-0.15
Registered design	0.90	0.04	0.11	-0.04	0.05	-0.20
Copyright	0.85	0.07	0.09	0.03	0.11	-0.05
Secrecy	0.80	0.12	0.19	0.18	0.12	0.12
Design complexity	0.85	0.12	0.04	0.08	0.15	0.04
Lead time advantage	0.79	0.15	0.06	0.14	0.16	0.15

Source: Balanced panel between UKIS2005, 2007 and 2009. Innovation active firms only. N=1,699. Rotated factor matrix of a tetrachoric correlation matrix. Rotation method is oblimin (0.5). Six factors with Eigenvalues greater than one are retained.

We make the following observations. First, there is consistency in the modes across the waves of the survey, i.e. over time, and across different sub-sets with the panels being biased towards larger enterprises.

Second, Factor 1, IP / technology innovating, is characterised by a high loading of the IPR variables together with the strategic protection methods – secrecy, design complexity and lead time advantage. This suggested that, on average, these are activities that are complementary. Formal methods are not used to substitute strategic protection methods and vice versa. Enterprises that protect their innovations with patents are also likely to use secrecy. The use of technical, industry or service standards as sources of information for innovation, also loads up on mode 1, additionally to loading on the mode related to codified knowledge.

Third, and with reference to Table 5.3, design expenditures and in-house R&D load up on three modes: IP/technology innovating, investing in intangibles and market-led innovating.

The three sets of innovation modes are saved in the form of factor scores, which are used as our estimates for six different innovation modes in the next part of the report.

5.2 Results: infrastructure and modes

This section explores the link between enterprises' innovation practices and their innovation environments with respect to: standards and measurement (combined score); certification (ISO 9001); and use of design consultancies. Table 5.4 provides regressions on modes using the UKIS2009 dataset.

Table 5.4 Mixed modes of innovation and infrastructure variables. Reference period is 2006 to 2008. Dataset is IS2009

	IP/techn. innovating	Investing in intangibles	Using codified knowledge	Wider innovating	Market-led innovating	External process modernizing
Combined score[a]	-0.01	0.02	0.01	0.00	0.02	0.01
	(0.00)*	(0.01)**	(0.01)+	(0.01)	(0.00)**	(0.00)*
ISO 9001[b]	0.00	0.01	0.01	0.00	0.00	0.00
	(0.00)+	(0.00)*	(0.00)**	(0.00)	(0.00)	(0.00)
Design consultancy	-0.02	-0.02	-0.01	0.01	-0.00	-0.02
	(0.01)*	(0.02)	(0.02)	(0.02)	(0.01)**	(0.02)
Human capital	0.01	0.06	0.05	0.03	0.02	0.01
	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**
International markets	0.05	0.13	0.07	0.05	0.05	0.01
	(0.01)**	(0.01)**	(0.01)**	(0.01)**	(0.01)**	(0.01)
Industry dummies	Included	Included	Included	Included	Included	Included

	IP/techn. innovating	Investing in intangibles	Using codified knowledge	Wider innovating	Market-led innovating	External process modernizing
Constant	-0.06 (0.03)*	0.17 (0.07)**	-0.00 (0.05)	-0.04 (0.05)	-0.05 (0.04)	0.10 (0.05)*
Observations	6,232	6,232	6,232	6,232	6,232	6,232
R-squared	0.07	0.12	0.09	0.04	0.06	0.02
F-statistic	17.05	40.53	26.70	10.59	16.38	4.72

Source: IS2009. Estimation method is OLS. We report robust standard errors in parentheses.

[a] combined score is measured in 2006

[b] ISO 9001 is the average stock of certificates in the current year

*** p<0.01, ** p<0.05, * p<0.1

The coefficients are small because of the unit of measurement of the dependent variables. Factor scores have a standard deviation of one (i.e. under the assumption of normal distribution 68% of observations are within plus/minus one). A change in combined score of one is associated with a 0.02 change in investing in intangibles. Combined score is associated with most innovation modes; and most strongly with investing in intangibles and market-led innovating. Combined score is not associated with using codified knowledge at the 10% level; because this mode indicates use of technical, health and safety standards as information for innovation we might have expected stronger results. We repeated the analysis measuring the modes in earlier reference periods and found the same pattern. The statistics can be found in the Appendix.

ISO 9001 is associated with investing in intangibles and using codified knowledge. When measuring the modes in 2004 to 2006 – taken from UKIS2007 with full results reported in the Appendix – ISO 9001 also shows a correlation with wider innovating.

There is no support for a correlation between design consultancy expenditures in an industry and increased use of a specific mode. On the contrary, we find two negative relationships, one with IP/technology innovating – which might be explained by an inward looking dimension to this mode – and market-led innovating. The latter is perhaps more difficult to explain. It is very likely that the exogenous design variable, is measured with substantial errors which materially affect these results.

5.3 Results: innovation modes and firm performance

This section examines, via regression analyses, the role that different innovation modes play, in conjunction with indicators of the wider innovation infrastructure, in driving performance and growth of enterprises. The measures that the models predict are basic measures of labour productivity, change in labour productivity, change in turnover and employment. Table 5.5 predicts labour productivity in the calendar year 2008.

Table 5.5 Impact of mixed modes, infrastructure variables on productivity in 2008

	Productivity Modes measured with no time lag[a]	Productivity Modes measured with a two year lag[b]	Productivity Modes measured with a four year lag[c]
IP/techn. Innovating	0.09 (0.06)	0.14 (0.04)**	0.21 (0.06)**
Investing in intangibles	-0.05 (0.03)+	0.03 (0.04)	-0.04 (0.04)
Using codified knowledge	0.13 (0.04)**	0.04 (0.04)	0.13 (0.05)**
Wider innovating	-0.00 (0.03)	0.04 (0.04)	0.01 (0.05)
Market-led innovating	-0.04 (0.04)	-0.08 (0.04)*	-0.03 (0.04)
External process modernizing	-0.10 (0.05)*	0.14 (0.05)**	0.08 (0.06)
Combined Score	0.08 (0.01)**	0.10 (0.02)**	0.10 (0.02)**
ISO 9001	0.02 (0.01)+	0.04 (0.01)**	0.01 (0.01)
Design consultancy	-0.06 (0.03)*	-0.04 (0.03)	-0.04 (0.04)
Log employment	0.97 (0.01)**	0.97 (0.01)**	0.96 (0.01)**
Human capital	0.12 (0.01)**	0.13 (0.01)**	0.13 (0.01)**
International market	0.45 (0.03)**	0.41 (0.03)**	0.43 (0.04)**
Industry dummies	Included	Included	Included
Constant	4.69 (0.16)**	4.41 (0.20)**	4.61 (0.25)**
Observations	6,192	3,472	2,687
R-squared	0.77	0.79	0.80
F-statistic	614.57	385.55	271.58

Source: IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses. The dependent variable is the natural log of turnover in 2008 with the natural log of employment in 2008 as right hand side variable. The coefficients on the key independent variables relate to percentage changes in turnover per employee in 2008.

[a] data is the UKIS2009. The reference period for the modes is 2006 to 2008.

[b] data is the balanced panel between IS2007 and 2009. The reference period for the modes is 2004 to 2006.

[c] based on the panel between IS2005, 2007 and 2009. The reference period for the modes is 2002 to 2004.

** p<0.01, * p<0.05, + p<0.1

Among the modes, IP/technology innovating and using codified knowledge, such as standards, are the two modes that show the strongest associations with productivity. Over and above the firm level enterprises that use codified knowledge, the industry and geographical level variables, combined score and ISO 9001 are also positively correlated with productivity, providing some support for the economic importance of such activities, feeding into increased performance through both firm level activities as well as at industry and county level. Investing in intangibles does not appear to lead to increased levels of labour productivity in the same period. External process modernizing is negatively associated with productivity in the current period, and positively and significantly related with productivity with a two-year lag. One possible explanation for the negative relationship in the regression without lags is that enterprises on average respond to low productivity level by seeking to upgrade their production processes, generating a negative contemporaneous relationship between productivity and process modernising.

Table 5.6 examines the effects on change in labour productivity in 2006- 2008. A similar pattern emerges, with IP/technology innovating, using codified knowledge, combined score and ISO 9001 showing a positive relationship with change in productivity.

Table 5.6 Impact of mixed modes, infrastructure variables on change in productivity in 2008

	Change in productivity Modes measured with no time lag[a]	Change in productivity Modes measured with a two year lag[b]	Change in productivity Modes measured with a four year lag[c]
IP/techn. Innovating	0.06 (0.03)*	0.06 (0.04)*	0.04 (0.04)
Investing in intangibles	0.00 (0.02)	0.00 (0.03)	-0.01 (0.03)
Using codified knowledge	0.04 (0.02)*	-0.00 (0.02)	0.06 (0.03)*
Wider innovating	0.03 (0.02)	0.03 (0.03)	0.04 (0.03)
Market-led innovating	0.00 (0.02)	-0.01 (0.03)	-0.00 (0.03)
External process modernizing	-0.01 (0.02)	0.05 (0.03)	0.06 (0.04)
Combined Score	0.02 (0.01)**	0.04 (0.01)**	0.04 (0.01)**
ISO 9001	0.00 (0.01)	0.02 (0.01)*	0.02 (0.01)*
Design consultancy	-0.02 (0.01)	0.00 (0.02)	-0.01 (0.02)

	Change in productivity Modes measured with no time lag[a]	Change in productivity Modes measured with a two year lag[b]	Change in productivity Modes measured with a four year lag[c]
Human capital	0.02 (0.01)**	0.05 (0.01)**	0.05 (0.01)**
International market	0.09 (0.01)**	0.13 (0.03)**	0.17 (0.04)**
Change in employment	0.59 (0.03)**	0.44 (0.04)**	0.45 (0.05)**
Productivity in t-1	-0.17 (0.02)**	-0.35 (0.03)**	-0.37 (0.04)**
Industry dummies included	Included	Included	Included
Constant	0.85 (0.10)**	1.55 (0.18)**	1.81 (0.21)**
Observations	6,014	3,456	2,561
R-squared	0.29	0.27	0.29
F-statistic	16.98	7.14	6.27

Source: IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses.

[a] data is the UKIS2009. The reference period for the modes is 2006 to 2008.

[b] data is the balanced panel between IS2007 and 2009. The reference period for the modes is 2004 to 2006.

[c] based on the panel between IS2005, 2007 and 2009. The reference period for the modes is 2002 to 2004.

** p<0.01, * p<0.05, + p<0.1

Tables 5.7 and 5.8 look at growth in turnover and employment respectively. The patterns of significant coefficients are very similar for change in turnover and employment growth as both act as a proxy for firm growth. The strongest patterns are found in the regressions without time lags, suggesting short-time benefits of the different innovation practices. As before, IP/technology innovating shows the strongest association, and similarly with respect to both lagged regressions. Wider innovating, investment in intangibles, and using codified knowledge all appear to matter. Wider innovating – which joins the managerial and marketing type innovations – remains significant also with time lags. Linked with the wider innovating mode, the share of firms with ISO 9001 certificates is also positively and significantly associated with growth, lending support to the importance of the stock of accredited certification to management standards.

Table 5.7 Impact of mixed modes, infrastructure variables on change in turnover in 2008.

	Change in turnover Modes measured with no time lag[a]	Change in turnover Modes measured with a two year lag[b]	Change in turnover Modes measured with a four year lag[c]
IP/techn. Innovating	0.11 (0.03)*	0.10 (0.03)**	0.07 (0.04)+
Investing in intangibles	0.04 (0.02)*	0.01 (0.03)	0.02 (0.03)
Using codified knowledge	0.07 (0.02)**	-0.00 (0.03)	0.07 (0.04)+
Wider innovating	0.07 (0.02)**	0.08 (0.03)*	0.12 (0.04)**
Market-led innovating	-0.01 (0.03)	-0.00 (0.03)	0.01 (0.03)
External process modernizing	0.00 (0.03)	0.05 (0.04)	0.04 (0.04)
Combined Score	0.00 (0.01)	-0.01 (0.01)	0.00 (0.01)
ISO 9001	0.01 (0.01)+	0.03 (0.01)**	0.03 (0.01)*
Design consultancy	-0.01 (0.02)	0.01 (0.02)	-0.01 (0.02)
Human capital	0.02 (0.01)**	0.04 (0.01)**	0.03 (0.01)*
International market	0.06 (0.02)**	0.08 (0.03)**	0.07 (0.03)*
Turnover in t-1	-0.07 (0.01)**	-0.10 (0.01)**	-0.10 (0.02)**
Industry dummies	Included	Included	Included
Constant	0.70 (0.09)**	0.98 (0.19)**	1.04 (0.19)**
Observations	6,036	3,462	2,570
R-squared	0.06	0.07	0.07
F-statistic	7.25	3.48	2.95

Source: IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses.

[a] data is the UKIS2009. The reference period for the modes is 2006 to 2008.

[b] data is the balanced panel between IS2007 and 2009. The reference period for the modes is 2004 to 2006.

[c] based on the panel between IS2005, 2007 and 2009. The reference period for the modes is 2002 to 2004.

** p<0.01, * p<0.05, + p<0.1

Table 5.8 Impact of mixed modes, infrastructure variables on change in employment in 2008.

	Change in employment Modes measured with no time lag[a]	Change in employment Modes measured with a two year lag[b]	Change in employment Modes measured with a four year lag[c]
IP/techn. Innovating	0.07 (0.03)**	0.06 (0.02)*	0.05 (0.03)
Investing in intangibles	0.04 (0.01)**	0.01 (0.03)	-0.01 (0.02)
Using codified knowledge	0.04 (0.02)*	-0.03 (0.02)	0.01 (0.03)
Wider innovating	0.04 (0.02)*	0.05 (0.02)*	0.06 (0.03)*
Market-led innovating	-0.01 (0.02)	0.00 (0.02)	-0.00 (0.03)
External process modernizing	0.01 (0.02)	0.02 (0.03)	0.03 (0.03)
Combined Score	-0.01 (0.01)	0.00 (0.01)	0.01 (0.01)
ISO 9001	0.01 (0.00)*	0.01 (0.01)	0.01 (0.01)+
Design consultancy	0.01 (0.01)	0.02 (0.02)	0.02 (0.02)
Human capital	0.01 (0.00)*	0.02 (0.01)**	0.02 (0.01)*
International market	0.01 (0.01)	0.06 (0.02)**	0.01 (0.02)
Employment in t-1	-0.06 (0.01)**	-0.06 (0.01)**	-0.05 (0.01)**
Industry dummies	Included	Included	Included
Constant	0.33 (0.06)**	0.10 (0.11)**	-0.08 (0.13)**
Observations	6,048	3,471	2,569
R-squared	0.06	0.04	0.03
F-statistic	9.86	3.50	2.16

Source: IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses.

[a] data is the UKIS2009. The reference period for the modes is 2006 to 2008.

[b] data is the balanced panel between IS2007 and 2009. The reference period for the modes is 2004 to 2006.

[c] based on the panel between IS2005, 2007 and 2009. The reference period for the modes is 2002 to 2004.

** p<0.01, * p<0.05, + p<0.1

This report set out to explore the role of some of the wider infrastructure bodies, their interplay with firms' innovation practices. We find support that both firm level and industry level use of standards, certification, publications alongside formal IPRs and other protection methods are at the heart of the performance enhancing mechanisms of innovation activities. This evidence suggests that further research into this relatively little explored and understood area is required to inform in greater depth on the economic impact of such activities. To this end, the next section supplements the empirical findings above with more detailed case study evidence.

6. Results: case study evidence on the role of accreditation

There is little economic literature on accreditation as a distinct constituent of the innovation system. The following paragraphs are an attempt to outline a few possible principles for an economics of accreditation. Accreditation is a cost effective way for buyers of specialised services to have confidence in their suppliers. There are a range of market mechanisms for establishing and maintaining the assurance that suppliers will deliver the specified products or services. These mechanisms include gaining a reputation for quality and reliability through the satisfactory experiences of customers - which can be costly to establish and maintain. Reputation can be developed through informal transfer of knowledge amongst users - word of mouth - but this route leaves uncertainty and risk on the demand side. There can be high transactions costs from searching for information on the quality of suppliers.

A system of certifying providers against a standard or norm can reduce these transaction costs by providing a guarantee that the suppliers have met objective criteria of competence. But in turn, the certifying body may be remote from the final user and the reliability of their judgements disputable.

Accreditation, essentially a system that audits the auditors, removes most of the remaining uncertainty by providing an external badge of competence for certifying agencies. This in turn puts the ultimate provision of services on or above a quality threshold by providing further assurance that those certificated by accredited agencies are of high quality and can be relied on. An economic rationale for welcoming this sort of codified assurance of competence and quality is along the following lines. As Peter Swann has argued, one role of a publicly validated system of measurement is to relieve information asymmetry between buyers and sellers. That is, sellers know the properties of the goods and services they offer, whereas buyers will typically be less well informed, leaving the risk that lower quality products can claim to be better than they are, reducing the price premium for genuinely higher quality and thus the incentive for incurring the costs of higher or improved quality or reliability. In the limit, this information asymmetry can results in the Gresham paradox, whereby lower quality goods dominate the market. An objective and independent system of measurement and quality standards can help to obviate this risk by providing buyers with equivalent information on product characteristics to that available to the suppliers. Higher quality or extended product characteristics can then be objectively measured and described, so that the customer can choose a higher price /quality option if that maximises his utility.

However, even where independent measurement and quality standards have been developed, there can remain a degree of uncertainty about whether they have been properly and reliably applied in a particular case. That is, claims that a published standard has been met can need independent verification. A system of verification that shows that suppliers in the market do use and meet the standard is a characteristic solution to this information asymmetry problem. But this solution can, in turn lead to second order information asymmetry concerning the competence and reliability of the verification process, since verifying bodies are themselves market agents, competing for the role of custodians of the standards and their correct and consistent application. So the age-old problem of quis custodiet ipsos custodes recurs. The system of accreditation was developed to deal with this problem and to create a further degree of confidence that markets in goods and services are underpinned by verifying bodies who are themselves audited. In the case of the UK, UKAS is the government appointed body that approves many verifying bodies, although it does not have an absolute monopoly of this role. Its competence and operations are assessed through peer review by other international accreditation organisations.

6.1 Impact case studies: the insurance of labs

Insurance brokers need to assess the level of risk awareness and the attitudes to and processes for risk mitigation and risk control in customers. Information provided by customers is one source of information but third party validation through certification and accreditation can be useful in corroborating or challenging the self-reported risk profile.

The use of accreditation of asbestos testing labs has been a major factor in restructuring the market for insurance for these businesses. A specialist broker of insurance for professional services firms perceived that the evidence of good systems for the awareness of risk and for its mitigation and management, given by accreditation, justified a lower premium rate, as claim level should be lower. Previous practice had been to regard asbestos testing as higher risk than other areas, with little or no variation according to the quality and effectiveness of the labs risk mitigation policies. Recognition of the accreditation as a signifier of quality enabled the insurance premia to be reduced by up to 40%, in an industry where insurance is a significant share of running costs. This confidence in the signal of good practice provided by accreditation has been borne out in practice, with a lower level of claims from the businesses concerned. The brokers and insurance companies then had the confidence to develop an insurance product for a broader range of labs operating in other areas of higher technical and health and safety risks. Accreditation as a mark of quality and compliance with best practices and the standards that embody them has thus led to innovation in insurance services. This lead has been followed by other insurers and competition has tended to diffuse the benefits of lower premia to a wider set of businesses, including those whose certification to standards is not by UKAS accreditation.

The pricing model works well for particularly hazardous substances or other sorts of high risk specialist services, as there is then scope for significant improvements in risk management and mitigation which can be externally validated. Other labs operate in areas with lower risks, with consequently less scope for economies in insurance costs through accredited compliance with standards. Additionally, UKAS requires accredited labs to have an insurance cover and sought a benchmark policy against which it could map the insurance covers of accredited labs.

In economic terms, the lower price for insurance is an indicator of real resource savings in the form of lower risks and reduced financial and social costs through fewer accidents and resulting damage. These benefits arise from the application of best practice in risk appraisal and management, enabled by the standard and by objective and expert assessment and accreditation.

6.2 Impact case study: Health-Diagnostic Imaging

A new standard - ISAS has been developed by the College of Radiographers and the Royal College of Radiologists, for best practice in running an imaging department. Accreditation to the standard is managed by UKAS. A number of imaging units have so far been accredited and interest is growing in others. The accreditation process for a unit involves assessment visits and inspection of documents recording their practices, by a team that includes both a senior radiographer and a consultant radiologist, as well as at least one lay representative, recruited and trained by UKAS and an accreditation professional.

The Standard is a comprehensive account of best practices, including how to treat patients efficiently and courteously. It is evidence based - the literature underpinning best practice is reviewed regularly and the source material is available to users.

Application and use of the standard in the accredited units has led to significant cost savings through more streamlined processes and better maintenance and accessibility of records such as patient details. One institution suggested that this might be of the order of 10% of costs, but that this could not be demonstrated with accounting information as the effects derived from general gains in effectiveness from improved management systems and staff's compliance with them. The patient experience has also improved through an emphasis on more information about their cases and the emphasis put on patient dignity. Without losing sight of their role in health provision as a public service, the accreditation process has supported the imaging units in being "business like" in asset management and customer focus. For example, diagnostic imaging equipment represent a major investment, and procedures to ensure regular maintenance of its technical condition and full operation are essential to obtaining maximum value from the investment. Disaster recovery plans are in place, and well known to staff. The imaging units that have achieved accreditation find that the learning effects of the process of reviewing, assessing and amending the systems of management and communication represent a major benefit of accreditation. It is frequently reported in the private sector that the initial learning and changes of attitudes and established practices, during the stage of implementing the standards and preparing for accreditation can constitute major ‘one-off’ gains. But also embedding the reformed practices in accessible guidance documents and in the organisation's culture, with regular re-assessment, ensures that the gains are maintained. The learning and adaption process in each case represented a significant level of costs, especially in the time of staff and management. But this investment has paid off.

Another benefit has been the signal that accreditation gives to the market about the quality of service and management systems and this has been of major importance for one of the accredited units, in contributing to winning a contract to supply imaging services to a health service trust. Similarly, accreditation to a well-defined standard for best practice can act as an indicator or compliance with the requirement of the Care Quality Commission, reducing the frequency and therefore the resource costs of, inspections by the CQC.

6.3 Impact case study: Health–Pathology Labs

Standards for pathology labs were developed over 20 years and the assessment and validation of compliance and its accreditation was administered by Clinical Pathology Accreditation, (CPA). This has now been acquired by UKAS, although still operates within UKAS as CPA, bringing pathology into the core of Accreditation practice. Assessments for accreditation are carried out by teams involving senior Pathologists and Accreditation professionals provided by or managed by CPA.

Major benefits of accredited status include:

- it reduces the need for inspections by regulatory agencies such as the Care Quality Commission.
- customer service is improved through e.g. well documented and accessible norms for customer treatment and communications
- risks of error is reduced through control of all key processes, such as codification of information on the age and shelf life of reagents and other chemicals used in the assay process
- all processes and their control are based on sound record keeping. Good and accessible record keeping is a key ingredient of the standard and its verifications.
- accredited certification can lead to lower costs of insurance against malpractice litigation, as procedures have been independently validated against the objective and independent standard, so that an audit trail is available in the event of legal challenge.

Nearly all pathology labs are now accredited to the CPA standard, involving assessment of technical competence: of staff, processes, test environment and traceability of measurements and the calibration of equipment, as well as management competencies in e.g. information and quality management systems and records management. UKAS are shifting the standards base for the system from CPA to the international standard ISO 15189, which covers the same areas of competence for practice in medical laboratories. These are essentially the same requirements as included in the CPA standards, but with the additional advantage of international comparability.

Accredited certification can act as a lower cost alternative to bureaucratic regulation and the associated costs of compliance. An example in the health sector is again in pathology – the case of a European directive on in vitro testing. This currently exempts in-house assays produced by pathology labs from the need for having them CE marked, which recognises their inherent expertise in making up their own testing kits from material kept under controlled conditions in the labs. In-house assays are often highly specialized in nature and their use can result in significant performance and economic benefit to the laboratory. Under a proposed amendment to the regulation, this exemption could be removed for all or possibly just for certain higher risk classes of test. The result of the loss of the exemption would be to increase the regulatory burden on laboratories significantly which is something that many laboratories would be ill equipped to accommodate. So under the proposals, test kits to be used would require CE marking, in effect resulting in many labs buying in rather that make up their own assay materials. The costs of this change have been roughly estimated to be around £40 m pa, for one healthcare organisation, which would pose an unacceptable increase in its budget. As all pathology labs are accredited to the CPA standard and will in due course be accredited to an ISO standard, the increased regulatory burden seems to have the potential to add to costs without any gains in patient safety. A possible alternative is to allow the exemption to remain as long as the laboratory is accredited to the relevant international standard, ISO 15189.

7. Conclusions

This report has drawn together evidence on components of the infrastructure that are major sources of information and stimulation for the national innovation system, and, thus, for innovation, productivity and growth. While building on existing studies, this report adds to our understanding of how the infrastructure institutions – BSI, NMS, IPO, UKAS, the Design Council and the varieties of knowledge they provide, have complementary and inter-locking roles and impacts in and through the system. This is the first UK based study, as far as we know, that has taken such a holistic approach to the evidence on the infrastructure and it provides part of the underpinning for the Infrastructure Initiative between BIS and the institutions concerned. The degree to which it has been possible to quantify these interdependencies is also new, as a mass of accumulated evidence from several waves of the UK Innovation Survey has been successfully integrated with indicators of the infrastructure from a variety of sources. We have thus been able to confirm and extend materially existing evidence developed for the infrastructure institutions taken individually. The main empirical and policy relevant findings include:

- The infrastructure is a key resource for the effective functioning of innovation and for economic performance more widely. Standards, design, accreditation, metrology and IP are all deeply embedded in the modes and styles of innovation practice across industry and commerce and in the public sector.

- They are complementary to, and supportive of, the other drivers of innovation, such as new technology, knowledge from the research base, organizational and managerial changes and marketing strategies.

- Notably, information from standards tends to be conjointly used with scientific and trade publications and with direct sourcing of knowledge from the research base.

- Certification to ISO 9001 by UKAS accredited bodies is positively and significantly associated with several modes of innovation and with productivity directly.

- There is a lack of systematic empirical evidence on the impact of accreditation. Although this report has used successfully an indicator for accredited management systems certification, there is a need for more research and analysis on the economic value of the accreditation system as a whole.

- The National Measurement System is part of or directly supports several types of innovation strategy and has a distinct impact on productivity.

- Design is complementary to other forms of investment in intangible assets, confirming the insights from the aggregate level innovation index project at NESTA.

- The innovation and efficiency promoting roles of the infrastructure are contributors to economic growth and productivity as well as to international competitiveness.

The analysis does though point to some areas where the relevant parts of the infrastructure, singly or severally, may be underutilized, supporting the rationale for the infrastructure initiative to explore the scope for more joint working and cross-referencing of the institution's offerings and relationships. The research set out here cannot lead to very specific proposals for action, but might suggest areas for further investigation by the institutions concerned. These include:

- Standards as a source of information do not feature strongly in the mode of innovation that emphasises process improvement and which tends to depend on external sources of information to enable the process improvements. As standards are, amongst other things, summary repositories of useable technical information, this might point to an area for further exploration.

- The overlap of standards and design in business innovation appears limited, although there is a body of standards for design management. Perhaps the design and standards worlds have some potential for exploring synergies.

- There is relatively low cross-fertilisation between IP and design, confirming the finding of Design Council surveys that the UK design industry are not themselves major users of design rights.

- More generally, the use of IP does not correlate highly with other areas of infrastructure, which may imply scope for more cross-referencing or to promoting knowledge portfolio management in businesses.

- Wider (managerial/organisational) innovation is less well correlated with QMS accredited certification, although the latter seems supportive of other types of innovation.

- Standards correlate with publications and direct information sourcing from the research base in a mode of innovation, supporting the initiatives underway to integrate research base outputs into standards making. The correlation of standards with publications suggests that published research outputs are appropriate forms of knowledge transfer of this integration, as well as direct researcher involvement.

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Appendix

Table A.1 Mixed modes of innovation and infrastructure variables. Reference period is 2004 to 2006. Dataset is the balanced panel between IS2007 and 2009

	IP/techn. innovating	Investing in intangibles	Wider innovating	Using codified knowledge	Market-led innovating	External process modernizing
Combined Score[a]	0.00	0.02	-0.01	-0.01	0.03	-0.01
	(0.01)	(0.01)**	(0.01)	(0.01)	(0.01)**	(0.01)
ISO 9001[b]	0.00	-0.00	0.01	-0.01	0.01	0.00
	(0.00)*	(0.01)	(0.01)**	(0.01)	(0.01)	(0.00)
Design Consultancy	-0.02	-0.03	0.00	-0.01	-0.01	-0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Human capital	0.03	0.03	0.04	0.05	0.03	0.02
	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**
International market	0.13	0.08	0.02	0.06	0.11	0.04
	(0.01)**	(0.01)**	(0.01)	(0.01)**	(0.01)**	(0.01)**
Industry dummies	Included	Included	Included	Included	Included	Included
Constant	-0.04	0.10	0.01	0.45	-0.04	0.15
	(0.09)	(0.08)**	(0.07)	(0.09)**	(0.09)	(0.09)+
Observations	3,946	3,946	3,946	3,946	3,946	3,946
R-squared	0.17	0.07	0.05	0.05	0.08	0.05
F-statistic	35.14	15.30	9.13	10.49	13.93	8.93

Source: Balanced panel between IS2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses.

[a] combined score is measured in 2006

[b] ISO 9001 is the average stock of certificates in the current year

*** p<0.01, ** p<0.05, * p<0.1

Table A.2 Mixed modes of innovation and infrastructure variables. Reference period is 2002 to 2004. Dataset is the balanced panel between IS2005, 2007 and 2009

	IP/techn. innovating	Investing in intangibles	Wider innovating	Using codified knowledge	Market-led innovating	External process modernizing
Combined Score[a]	-0.00	0.01	0.01	0.00	0.02	-0.00
	(0.01)	(0.01)	(0.01)+	(0.01)	(0.01)*	(0.01)
ISO 9001[b]	0.00	-0.01	-0.00	0.00	-0.00	-0.02
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)**
Design Consultancy	0.02	0.02	-0.03	0.02	-0.04	0.06
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)+	(0.02)**
Human capital	0.03	0.06	0.03	0.05	0.04	0.01
	(0.00)**	(0.01)**	(0.01)**	(0.01)**	(0.00)**	(0.00)**
International market	0.17	0.03	0.02	0.08	0.09	0.06
	(0.01)**	(0.02)	(0.02)	(0.02)**	(0.02)**	(0.02)**
Industry dummies	Included	Included	Included	Included	Included	Included
Constant	0.01	0.33	0.23	0.11	-0.07	0.10
	(0.09)	(0.11)**	(0.10)*	(0.09)	(0.07)	(0.07)
Observations	3,064	3,064	3,064	3,064	3,064	3,064
R-squared	0.18	0.08	0.04	0.08	0.10	0.05
F-statistic	25.94	11.86	5.50	12.85	13.47	7.47

Source: Balanced panel between IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses.

[a] combined score is measured in 2004

[b] ISO 9001 is the average stock of certificates in the current year

*** p<0.01, ** p<0.05, * p<0.1

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