The Economics of Accreditation

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Executive Summary

This paper is a report on a research project on the economics of accreditation in the UK. The main motivation and objective for the study is to have available a detailed analysis of how the accreditation system impinges on important aspects of economic life, such as innovation and business and economic performance. It aims to improve the general understanding of the benefits of using accredited conformity assessment and to help businesses make informed decisions when procuring conformity assessment and related services. It is also intended to be helpful to government by supporting evidence-based policy making in relation to accreditation and conformity assessment.

Background: the role of conformity assessment and accreditation

The effective operation of markets needs buyers and sellers to be confident in the reliability and competence of their (trading) partners and in the information they provide on the properties of goods and services offered. There are a variety of ways in which market agents can develop the knowledge and confidence in goods and services. These included repeated purchases from one or several suppliers, to test suitability of the good or service and the reliability of the supplier. This is of course costly especially for high value, infrequently purchased or safety critical items. Buyers can instead depend on the reputation of suppliers as a signal of quality and confidence.

An alternative source of confidence in the capabilities of suppliers of such critical goods and services is the implementation of standards for performance and the evolution of conformity assessment as a way of ensuring that the suppliers proceed consistently with the standard and so can be relied on. Accreditation reinforces conformity assessment by providing an external badge of competence for the assessment bodies.

Accreditation is the external validation of organisations offering conformity assessment services eg calibration, testing, inspection and certification. When products, services, processes or organisations are evaluated by a third party conformity assessment body, accreditation offers an additional, top-layer quality assurance by assessing the competence and impartiality of the conformity assessment bodies. This is done by accrediting the organisations offering conformity assessment to a recognized standard, for example ISO 17025 in the case of laboratories, and ISO 17020 in the case of inspection bodies. A list of the relevant standards is at Annex E.

This role can amplify the impacts of each conformity assessment service, and of the system as a whole. For instance, as accreditation increases the credibility of test results and certificates, producers can gain greater commercial benefits from the products and services offered. This is particularly the case where innovative goods and services are concerned, creating incentives for further innovation related investment. .

United Kingdom Accreditation Service (UKAS)

Accreditation increases the confidence in the work and findings of conformity assessment bodies. In the UK, accreditation applies for a specific period of time, usually 12 months, after which the conformity assessment body is re-assessed. Through arrangements for mutual recognition of test reports and certificates of conformity across countries, accreditation facilitates international trade. Accreditation can also indirectly raise the competencies of

services through the transfer of knowledge from the accreditation institutions to the assessed organisations and laboratories. As well as commercial uses, conformity assessed services have impacts on public services, in particular health and welfare through applications in the health services or economic activities with health risks, such as the detection and treatment of asbestos in buildings. National accreditation bodies need to be independent, impartial and recognized nationally and internationally.

Government recognised accreditation in the UK is the responsibility of the National Accreditation Body, the United Kingdom Accreditation Service (UKAS). UKAS is a non-profit-distributing private company limited by guarantee. UKAS is the sole national body recognised by the government for accreditation of calibration and testing laboratories and inspection and certification bodies, against national and international standards, . UKAS 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 the Department for Business, Innovation and Skills (BIS).

The accreditation framework managed by UKAS differs from other types of accreditation, for example of educational establishments, through its basis in sets of agreed national and international standards, for the conduct of certification, inspection, testing and calibration bodies.

Data: the UKAS/BMTA survey

The report systematically analyses interview and empirical evidence on the impact of accreditation and the quality infrastructure of which it is a part. It draws on published and policy related literature and studies, and examines both primary and secondary empirical data. These include a number of interviews with stakeholders, including recently accredited laboratories. Another important source of information is a study of the commercial benefits to its customers of services provided by the National Physical Laboratory (NPL), whose results have kindly been made available. A new survey of 176 suppliers of accredited services, - calibration and testing laboratories, certification and inspection bodies was carried out specifically for this study.

This survey, referred to as the UKAS/BMTA Survey has helped to establish the perception and value added of UKAS accreditation for suppliers and users of services. The survey was sent to members of the British Measurement and Testing Association (BMTA) and UKAS customers and was completed by 176 businesses active in these services, with nearly 70% having their main activity in testing, followed by 27% in calibration, 16% inspection and 13% certification. There are also 11% of responses from manufacturing firms that provide accredited services through in-house laboratories. Averaged across all conformity assessment services, around 45% of the market is in accredited services, but with higher shares in calibration and lower shares in inspection. The majority of respondents who answered the question reported that prices for accredited services were higher than for non-accredited services, on average by an estimated 8%.

The survey also confirmed the impression from interviews, that for most businesses, the advantages of gaining accreditation are commercial, and do not derive from a regulatory requirement. For example 50% of respondents considered that accreditation was a marketing and reputational advantage, while a further 16% felt that it was a requirement of their customers and nearly 20% reported benefits in efficiency and service quality from the

assessment process. There are also important learning and efficiency enhancing effects from the processes of assessment for accreditation. Our interviews indicated that even large service suppliers, who have the option of relying on their own reputation, find accreditation by UKAS confirms and enhances that reputation and that they were able to make gains in efficiency, for example in staff management and training, as a result of undertaking the UKAS assessment.

Key findings: the economic impact of accreditation

Attempting to estimate, in monetary or equivalent terms, the impact of UKAS accreditation presents considerable challenges as accreditation is an additional layer of assurance in a complex quality infrastructure that could operate without it. So to identify and quantify the added value of UKAS requires evidence on the effects in each area of conformity assessed services. This, in turn, needs to rest on the economic and social value delivered by the services themselves. An indicator of the effect of UKAS accreditation on that value is needed to complete the calculation.

This report identifies, and provides first estimates, for a number of channels of impact of accreditation on economic life and values. For one, important channel – the commercial benefits to service suppliers and users – it has been possible to arrive at indicative monetary valuation of benefits. This has used the extent to which market prices for services are higher for the accredited version as the indicator of the marginal effect of adding UKAS accreditation of conformity assessment bodies to the delivery of services. We interpret this margin as the 'willingness to pay' for what accreditation of the service provider to an exogenous standard offers. Based on these price premia, an estimate of market sizes, and the shares of accredited in total services, the benefits of UKAS accreditation to conformity assessment bodies would amount to around £295m per annum.

But in addition, there are substantial downstream impacts on industry and commerce via the quality infrastructure. Estimations using – among other data sources - the UK innovation surveys suggest that higher intensity of use of the national measurement system (NMS) is positively correlated with several types of innovation and directly with proxies of labour productivity and growth. These impacts are underpinned by UKAS as around 50% of NMS services are from accredited suppliers. Similarly, we find a positive and significant correlation between the intensity of accredited certification to ISO 9001 and types of innovation and also productivity, which gives additional support to evidence from literature and case studies. The model quantifies the innovation and productivity effects of accreditation supported services in terms of estimated parameters and tests of statistical significance, which is as far as economic analysis of impact usually goes. These impact indicators cannot be translated directly into monetary values, because of the nature of the data used in their estimation.

However, it has been possible to develop indicative monetary values of these downstream effects, on the basis of the multiplier of UKAS accreditation on other dimensions of the quality infrastructure. The multiplier can be derived from the UKAS/BMTA survey while indicators of the commercial benefits to users from the services of accredited suppliers have been based on survey data kindly made available by the National Physical Laboratory, which have been taken to be indicative of the value of accredited measurement services overall. This broad estimate of downstream commercial benefit amounts to approximately £320m per annum.

Together with indicators of the perceived business value of accreditation to service suppliers, reported in the UKAS/BMTA survey, an indicative estimate of value generated by UKAS jointly for suppliers and users, through the quality infrastructure is, in round figures, some £600m per annum. This represents only those commercial benefits where financial indicators could be derived.

Additionally, the following channels of impact can be identified, although for reasons briefly outlined in the relevant sections, it has been beyond the resources of this study to undertake the research and evidence gathering that would enable quantification, as each type of impact requires very specific indicators which are not currently available. It is though a plausible assumption that the totality of these benefits would be very substantial. But it is impossible to make even an educated guess at the order of magnitude.

- Public health and safety are advanced by accredited services in areas as diverse as diagnostic imaging, pathology labs, forensic testing, water quality and the management of the risks from asbestos in buildings.
- International trade is enabled through the assurance of quality and reliability while international mutual recognition of accredited testing and certification reduces potential barriers to trade.
- Efficiency in industry is promoted by accreditation support for the integrity of the National Measurement System, which inter alia leads to the avoidance of costs, for example of waste and re-working arising from non-conforming measurement.

Implications

In sum, the extensive theoretical and empirical evidence gathered here, in what is the first detailed study of the impacts of UKAS accreditation, suggests that there are substantial benefits of accreditation in the quality infrastructure and the innovation system more generally. This implies that UKAS accreditation is a resource for innovation and efficiency, and that accredited services could beneficially be more widely adopted in both the private and public sectors. Further, the economic, public health and welfare and international trade benefits deriving from an independent accreditation body reinforce the merits of government policy on accreditation more generally.

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1 Introduction

This paper is a report on a research project to cover the economics of accreditation in the UK. The main motivation and objective for the study is to have available a rigorous and detailed analysis of how the accreditation system impinges on important aspects of economic life, such as innovation and business and economic performance. It aims to improve the general understanding of the benefits of using accredited conformity assessment and to help businesses make informed decisions when procuring conformity assessment and related services. It is also intended to be helpful to government by supporting evidence based policy making in relation to accreditation and conformity assessment.

The report systematically analyses interview and empirical evidence on the impact of accreditation and the quality infrastructure of which it is a part. It draws on published and policy related literature and studies including a recent report on the wider innovation infrastructure (Frenz and Lambert 2012). It further examines both primary and secondary empirical data. Two types of primary data are collected: (a) a number of interviews with different stakeholders, including recently accredited laboratories; and (b) 176 survey responses from suppliers of accredited services, e.g. calibration labs and inspection bodies. The report further draws on the following datasets: (a) data from a survey of over 500 customers, kindly made available by the National Physical Laboratory in which information is collected from customers; (b) the UK Innovation Survey collected on behalf of the Department for Business, Innovation and Skills (this is the UK version of the Community Innovation Survey); (c) a survey of firms that have achieved certification against a Quality Management Standard conducted by the International Accreditation Forum; (d) Quality Register data on certification to management standards reported to TSO ; (e) data on the number of standards and scientific and precision equipment purchases compiled by Paul Temple (Temple 2009).

The report is organised as follows. Section 2 contains a review of the underlying principles of the quality infrastructure and the role of accreditation and of UKAS. Section 3 turns to the relevant economic theory and examines existing empirical evidence on the role of conformity assessment. The majority of this empirical evidence is based on management system certification, because data is readily available in that area. Section 4 presents results based on analyses of survey data: a survey of 176 UKAS customers carried out for the purpose of this report; and a survey of around 200 UK firms that replied to the International Accreditation Forum survey. Section 5 uses the survey results together with official statistics to deduce an indicative estimate for the impact of UKAS accreditation. Section 6 sets out the channels of impact for accreditation including effects in the market place, on economic performance, international trade and on public health. Section 7 concludes with the main findings from this report, its limitations, areas for future research and policy recommendations.

We carried out a number of interviews with UKAS staff, individual experts, trade associations, conformity assessment bodies and businesses in calibration, testing, inspection and certification services. We are very grateful for their time and willingness to share knowledge. Much of the material from the interviews is used in subsequent sections in conjunction with other types of evidence, to provide a more rounded account of the impacts of the accreditation system. But we have not attributed items of information or opinions to individuals or organisations.

2 The role of accreditation

This section first provides a description of what accreditation is and how it fits in the quality infrastructure of an economy before discussing the benefits to businesses of accreditation and use of accredited services.

2.1 Accreditation and the quality infrastructure

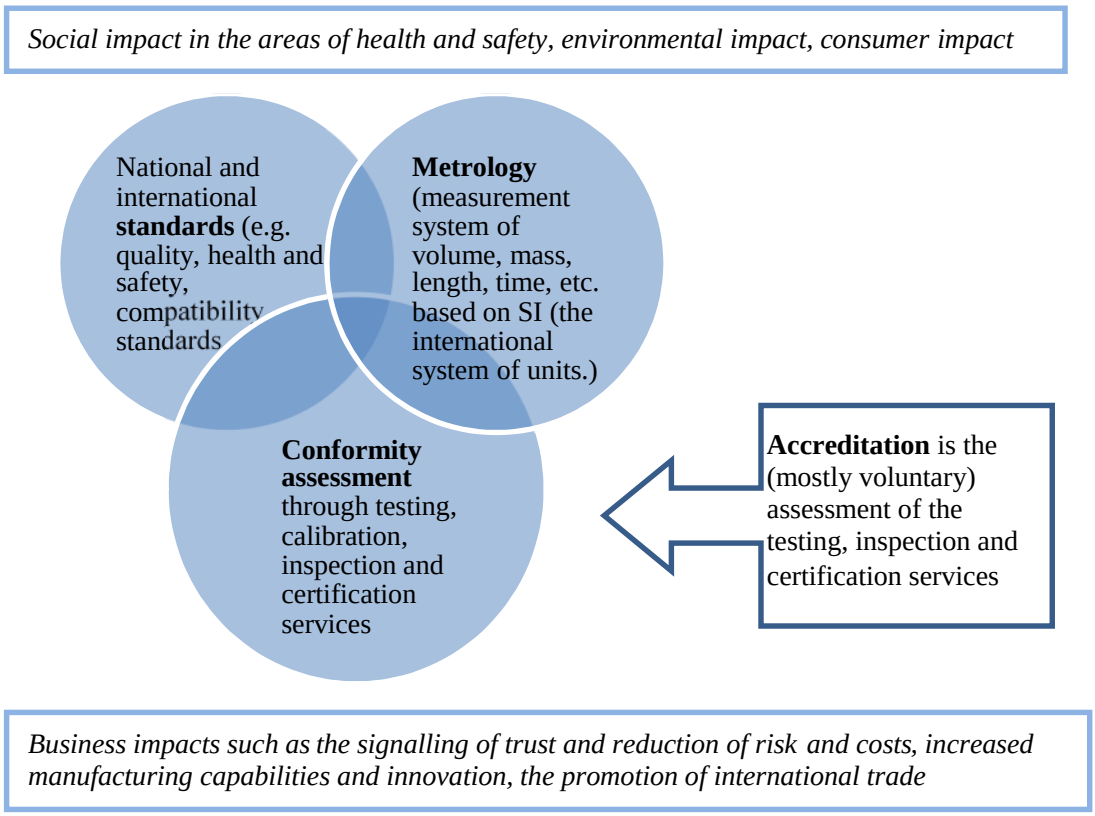
Accreditation forms part of a country's quality infrastructure. It is part of a system that assesses if a product, service, business process or an organisation conforms with a specific standards (e.g. quality or health and safety standards).

Often organisations self-assess and declare that their products or services follow a specific standard. Instead of self-assessment, a business can consult an external assessor to verify conformity with the standard. This is typically done to increase trust on the side of the end-users that in fact the standard is met.

In the case of external assessors these might be self-appointed organisations, or they might be created by a trade association, or some other form of agreement between the businesses in an industry, in order to provide external validation of the use of the standard. In some industries, major OEMs will exert de facto "quality standards." Collectively, the assessors in this field are commonly referred to as 'conformity assessment bodies' and typically carry out activities such as calibration, testing, inspection and certification.

Accreditation is the external validation of conformity assessment bodies, and the independent testing of the effectiveness of external assessors. It is about *'assessing the assessors'*. When products, services, process or organisations are evaluated by a third party conformity assessment body, accreditation offers an additional, top layer of quality assurance by ensuring the competence and independence of the conformity assessment body. This is done by accrediting the conformity assessment body to an established standard, ISO 17025 in the case of laboratories, and ISO 17020 in the case of inspection bodies (e.g. Guasch et al., 2007). Figure 1, adopted from Guasch et al. (2007) summarises the quality infrastructure and places accreditation within it.

Figure. 1 The quality infrastructure



Source: Adopted with substantial amendments from Guasch et al. (2007)

2.2 The quality infrastructure

The institutions, legal frameworks and bodies of knowledge that make up the quality infrastructure are vital parts of modern economies and international connections through trade and the movement of labour and capital. They are central to the effective operation of a national innovation system and to efficiency in production, distribution and trade in goods and services. They have a set of salient characteristic that provide valuable information, facilitate markets, economic activity and international trade. These are, in turn, underpinned and their functioning enhanced by national accreditation systems and the international links between them. These characteristics include:

- *Confidence.* Products and services conform to their stated characteristics.
- *Reliability*. The quality infrastructure enables trust in the measurements units and procedures, the materials or methods that are used and the integrity of their use.
- *Comparability* of products and services across countries or regions.
- *Traceability.* "An uninterrupted chain of comparison measurements with increasingly higher accuracy instruments (smaller measurement uncertainty), starting at the instrument used in industry up to the national measurement standard." (Sanetra and Marbán, 2007, p. 63)
- *Competence.* Institutions in the quality system are technically capable.
- *Conformity.* Products and processes meet the requirements of a standard.
- *Transparency.* Practices and procedures of the involved institutions are accessible

- *Impartiality*. Institutions need to be protected from political and commercial influence and regulatory capture.

Definition of conformity assessment

> *" 'Conformity assessment' is the term given to the processes that are used to demonstrate that a product, service or management system meets specified requirements. These requirements are contained in ISO/IEC International Standards. The use of ISO/IEC standards in conformity assessment procedures allows for harmonization throughout the world and this, in turn, not only facilitates international trade between countries, but also facilitates trade within countries by giving the purchaser of the product or service confidence that it meets requirements."*
> *Source: International Organization for Standardization*

Conformity assessment in a quality system assesses whether goods and services conform to a standard. Conformity assessment has a scaling up effect on the economic benefits from metrology, standardisation and management systems certification by a clear labelling of the services that meet the internationally agreed standards. This increases the information for consumers and creates incentives for producers to upgrade their processes and innovate in goods and services. As elements of the conformity assessment framework testing, inspection and certification services can be distinguished.

- Testing, inspection and certification activities reduce risks for suppliers and customers so promoting investment.
- More accurate measuring equipment increases the returns form research and development.
- The benefits of certification accrue to producers and consumers.
- Producers who can objectively demonstrate compliance with a standard are able to differentiate their products, gain market share and achieve premium prices, with an incentive for further innovation.

2.3 Accreditation

The position and contribution of accreditation to the quality infrastructure can be summarised as follows:

The main function of accreditation is to assess the competence of organisations carrying out conformity assessment, and so support trust in the quality infrastructure. This role can amplify the impacts of each conformity assessment service and thus of the system as a whole. For instance, as accreditation increases the credibility of test reports and certificates, producers can gain greater commercial benefits from the products and services offered. This is particularly the case where innovative products and services are concerned, creating incentives for further innovation related investment. Accreditation bodies independently assess the competences and processes of systems certifiers and calibration, inspection and testing services, and thus provide an assurance of conformity with international standards for these services.

Accreditation is, thus, a means of building confidence in the work and the findings of conformity assessment bodies. It applies for a set period of time and includes regular re-assessments. Through arrangements for mutual recognition of test reports and certificates of

conformity, accreditation facilitates international trade. Accreditation reduces risk for government, business and customers by ensuring, through regular surveillance, that conformity assessment bodies are both independent and competent.

Accreditation can indirectly raise the competencies of services through transfer of knowledge from the accreditation institutions to the assessed laboratories (Gilmour and Loesener, 2003). Accreditation bodies need to be independent, impartial and recognized internationally. When that is so, they ensure competence, confidence, reliability, transparency and political independence.

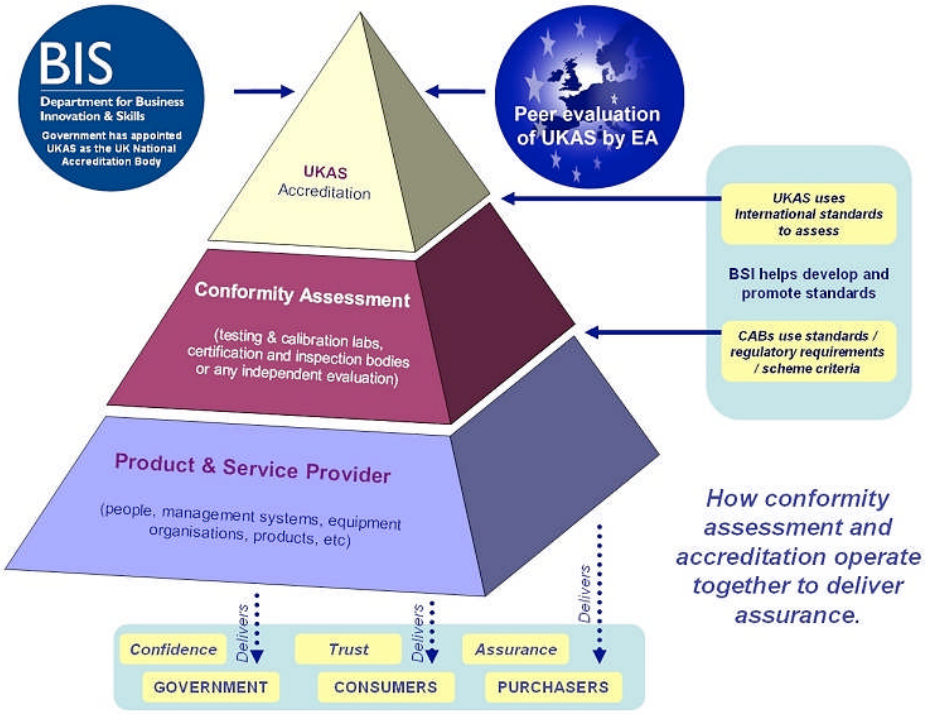
2.4 The United Kingdom Accreditation Service

Government recognised accreditation in the UK is the responsibility of the National Accreditation Body, the UK Accreditation Service (UKAS). UKAS is a non-profit-distributing private company limited by guarantee. UKAS is the sole national body recognised by the Government for the accreditation, against international standards, of calibration and testing laboratories and inspection and certification bodies. UKAS 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 the Department for Business, Innovation and Skills (BIS).

The accreditation framework managed by UKAS differs from other types of accreditation, for example of educational establishments, through its basis in sets of agreed national and international standards, against which UKAS assesses bodies.

In turn, the conformity assessment bodies assess the competence and conduct of businesses and public sector bodies or provide services such as product testing or equipment calibration supported by the user confidence generated by accreditation. UKAS manages the system and is at the top of the accreditation traceability tree, as shown in Figure 2 published by BIS.

Figure 2. Positioning of UKAS in the economy



Source: The UK Department for Business, Innovation and Skills.

UKAS has 180 full-time staff of whom 70% are technical, supplemented by a pool of 250 contract technical assessors. UKAS operates in most industries, including scientific and technical activities but also management systems. UKAS is organised internally as follows:

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

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.

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. Quality Management Systems 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.

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.

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 accredited conformity assessment results across Europe irrespective of the issuing EU country of origin. This helps to enable open trade between European countries, by reducing non-tariff barriers, 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.

2.4.1 Management Systems Certification

UKAS provides accreditation for a set of certification bodies that audit businesses (including some in the public sector) against a number of management process standards. These include the fields of Quality Management Systems, using the ISO 9001 standard; and Environmental Management Systems, using ISO 14001.

Not all certifying bodies are accredited; some offer their services based on reputation or price competitiveness. Others are accredited by bodies other than UKAS.

The effects of certification may be expected to arise in three broadly defined forms. Business efficiency should be enhanced through the adoption of more effective management systems.

In conjunction with the firm's own competencies and capabilities, better processes may raise competitiveness in the market, while the 'flag' of certified Quality Management Systems can be a prominence signal that raises customer confidence that here is a soundly managed business partner, while the particular case of environmental management can show the potential for sustainable processes.

Arguably, the firms innovation potential may be enhanced through well organised processes that enable resources including management and skills to be devoted to innovation related investment and preparations. Again, the signal to the market of certified management systems could encourage potential customers for innovative products or services, or induce partnerships for open or distributed innovation.

2.4.2 Calibration, testing and inspection

The accurate calibration of measuring equipment is self-evidently essential for business efficiency, as the costs of measurement errors through scrappage, re-working, down time and customer dissatisfaction are obviously high. As part of the present study we sought information on the incidence and scale of these costs, in order to get an indicator of the benefits of reliable calibration service and thence of the value, through quality assurance, of accredited calibration. But it emerged from inquiries that such information is not readily available. It may not be systematically collected or not easily accessible for reasons of commercial confidentiality. It should in principle be possible to survey businesses on the extent and scale of such costs, using an approach that guarantees anonymity of the information provided. Such a study was beyond the scope and resources of this project. Although the use of measuring equipment as part of business processes is often discussed only for manufacturing, it is clearly the case that many services sectors use technologies that require accurate measurement. For example, accurate flow measurement is vital in gas and water supply and in petrol wholesaling and retailing.

Accurate and reliable calibration and testing are also potentially innovation promoting. An important part of product innovation involves adding to or enhancing the range of user benefits that a product provides. The ability to introduce and modify these product characteristics can be increased by advances in the science and application of metrology and measurement standards (Swann 1999, 2010). But the availability in house or from a reliable testing business of product testing services is also essential for successfully introducing new or significantly improved products and services. This is likely to be especially the case for high technology, high value or safety and environmentally critical innovations.
And the application of metrology advances rests on reliable calibration of existing and new measuring equipment.

3 Background: the economic impact of accreditation

Following on from the description of accreditation within the quality infrastructure and the position of UKAS in the UK, we turn to the impact of accreditation. The benefits include, but are not limited, to (a) the signalling of trust for suppliers, coupled with the reduction of risk for the end-user, (b) increased manufacturing capabilities and innovation, and (c) the promotion of international trade.

A key benefit associated with accreditation and quality assurance is a risk reduction for end-users. Over and above the risk reduction for the end user, accreditation might also increase the efficiency or competencies of in-house research labs. This occurs when the evaluator transfers knowledge as part of the evaluation process to the organisation that is being assessed. But, accreditation is both costly and time consuming, and it requires substantial investment into knowledge creation and learning on the part of the accreditation body. As a result, for accreditation services to be available, it might require a threshold of demand for a specific service or to be legal requirement, as if for example the case for asbestos removal (Guasch et al, 2007).

3.1 Economic theory of accreditation

There is little economic literature on accreditation as a distinct constituent of the innovation system or on the role of the quality infrastructure in general. The role of accreditation is implicit in some recent analysis of how standards support business innovation, by acting as a source of reliable and specific information that can be applied in the development and improvement of products and processes. Similarly the National Measurement System has a substantial impact on business and economic performance and this rests in a major way on the operations of the calibration and testing laboratories and companies, many of whom are accredited by UKAS. Some indicative analysis of how the UKAS labs make their contribution has been included in economic analysis of the role of the NMS in the national innovation system. (e.g. Lambert (2010), Temple (2009)). Recent work, set out in more detail below, has begun to identify and estimate the specific impact of at least some dimensions of the accredited conformity assessment bodies (Frenz and Lambert 2012). This is essentially empirical and there has not been a full theoretical treatment of the topic in the economics literature. The following paragraphs, therefore, are an attempt to outline a few possible principles for an economics of accreditation.

The effective operation of markets needs buyers and sellers to be confident in the reliability and competence of their trading partners and in the information they provide on the properties of goods and services offered. There are a variety of ways in which market agents can develop the knowledge and confidence in goods and services. These included repeated purchases from one or several suppliers, to test suitability of the good or service and the reliability of the supplier. This is of course costly especially for high value, infrequently purchased or safety critical items. Buyers can instead depend on the reputation of suppliers as a signal of quality and confidence. Much investment by firms in branding and the use of trademarks serves to establish or enhance reputation. But this source of confidence can, in some circumstances, serve to inhibit the entry of new suppliers and the extent of competition. 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.

Other forms of assurance include a regulatory or market requirement for particular qualifications. Professional services including law, medicine, accountancy etc. specify qualifications, often, as in the case of medicine and law, involving practical experience as well as formal education.

The issue of confidence is more acute where the potential costs to the customer of poor performance or errors in goods or services are high, such as safety critical uses or high social or environmental costs of such errors. (The continuing importance and the regulatory requirement for testing for asbestos to be undertaken only by accredited labs is a case in point).

An alternative source of confidence in the capabilities of suppliers of such critical goods and services is the implementation of standards for performance and the evolution of conformity assessment as a way of auditing that the suppliers indeed proceed consistently with the standard and so can be relied on. 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 judgments disputable.

Accreditation, essentially a system that audits the auditors, removes much of the remaining uncertainty by providing an external badge of competence for testing and 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. This can thus act as a deterrent to innovation. In the limit, this information asymmetry can result in the Gresham paradox, whereby lower quality goods dominate the market. An objective and independent system of measurement 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 standards have been developed, there can remain a degree of uncertainty about whether they have been properly and reliably applied. That is, claims that a published measurement standard has been met need independent verification. A system of certification 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 certification process, since certifying 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 who will audit the auditors 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 certifying agencies who are themselves audited and guaranteed objectively and independently.

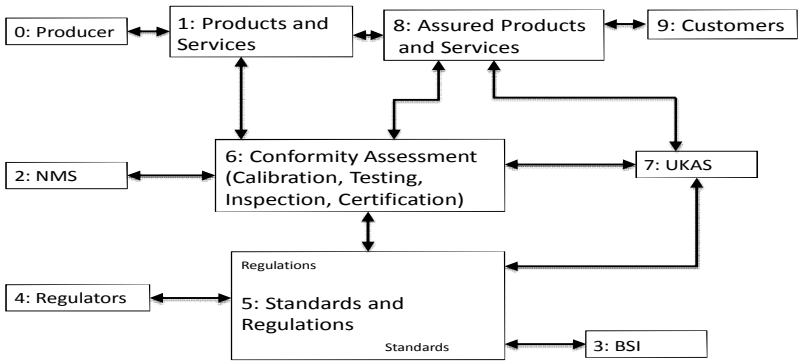
In the case of the UK, UKAS is the government recognised organisation that provides assessment of service provides against accepted standards developed by the International Organization for Standardization, although it does not have a monopoly of this role. Its own competence and operations are assessed through peer-review by other international accreditation organisations.

3.2 A model of the quality infrastructure

The relationships between the elements of the quality infrastructure, including accreditation, set out in general terms in Figure 1 can be given a more operational form. Such a structure has been very kindly provided by Professor Peter Swann and is an application to the case of the quality infrastructure of some more general principles that he has developed and which will appear in a new book on 'Common Innovation' (Swann, forthcoming).

Based on a mathematical model Professor Swann's analysis shows how the effect of each institution in the quality infrastructure is amplified by the role of UKAS. This set of interdependencies and cross-amplifying effects can be usefully represented in a flow chart (Figure 3).

Figure 3 The quality infrastructure



Source: Swann (forthcoming) with very minor amendments.

The model can be expressed in mathematical form, enabling identification of the 'multipliers' and so pointing to the scope, and information required for quantification of the internal links in the model and the cumulative effects of the quality infrastructure on the economy. As noted earlier, limitations of data availability have meant that only some aspects of these impact relationships have been subject to empirical estimation in this report. Professor Swann's model does, though, provide a sound theoretical basis for possible future exercises to extend the coverage of evidence based impact estimates.

UKAS and other quality infrastructure institutions. From the flow model, we can identify the multipliers between UKAS and other institutions or their outputs that support the quality infrastructure. Some of the key interdependencies are discussed below.

The British Standards Institution (BSI). BSI, and similar international standards bodies, can influence the effectiveness of standards by the choice of standards to pursue and the efficiency and effectiveness of the process. UKAS can have an effect on BSI's decision making and on the formulation of standards, through its expertise in accreditation processes and the standards for conformity assessment. The impact by this route may be assumed to be small, relative to the route through affecting the use and effectiveness of standards themselves. UKAS also participates in international standards bodies, such as the International Organization for Standardization (ISO), and is influential in international accreditation bodies: the International Accreditation Forum (IAF) and the International Laboratory Accreditation Cooperation (ILAC).

Regulators. UKAS can interact with regulatory bodies through the availability of an accreditation framework that can enable market based provision of services compliant with regulations. This can be a cost effective alternative to say government or regulator appointed enforcement bodies and the bureaucratic procedures that can be associated with them. This 'light touch regulation' effect would be manifest in lower costs of achieving the objectives of regulations.

*Standards and regulations***.** Accreditation of conformity assessment bodies and processes supports and enhances the effects of an important sub-set of standards. A possible indicator for the multiplier role of accreditation is the share of the stock of standards that have accredited conformity assessment support. This indicator could be modified by the reach of these standards, i.e. does accreditation apply to standards that are more important for economic performance or public welfare?

In the following we survey some of the existing empirical literature that investigates the benefits to businesses of accreditation and conformity assessment services.

3.3 Empirical literature on the role of conformity assessment

There are no studies that look explicitly at the economic impact of accreditation as a whole. Gonçalves and Peuckert (2011) link this to the empirical difficulties in isolating the contribution of accreditation services to other functions of the quality infrastructure. Most closely related to the impact of accreditation is the existing empirical evidence that comes from studies that investigate the role of conformity assessment, largely conformity with certain quality standards, e.g. in management systems or environmental management information systems. Conformity assessment to ISO 9001 is a well-documented area because the empirical datasets are compiled and made available by ISO.

There is no or little economics or management literature on more technical conformity assessment, which includes important parts of the innovation infrastructure such as calibration and testing labs, inspection bodies and associated proficiency testing bodies.

The available literature appears to consist mainly of practical guides, for example, to the definition and estimation of degrees of uncertainty in measurement. A useful guide for

businesses who need to procure calibration services has been prepared by Gambica (2008). This includes sections on what can be covered by a calibration. This can range from simply measuring the performance of an instrument against its specification to adjusting the instrument back to its specification. Interestingly, the guide's advice is based on seeking a calibration service level that is fit for purpose and it asserts in several places that accredited calibration is not necessarily better than non-accredited.

The benefits of accredited services are picked upon in some of the trade literature. One such example is a recent article in Lux Magazine, a magazine for the lighting industry (Miller 2012). The lighting industry faced with increased number of national and international regulations, for example, in the area of energy efficient lighting is likely to see an increased demand for testing and calibration services. The Lux article suggests that much of the testing labs in that industry are not yet accredited by UKAS, either at all or for the relevant tests. The article strongly points towards specific benefits of accredited testing services leading to increased market shares and learning from services carried out by accredited labs.

In a report on the wider innovation infrastructure we examined the impact of quality management standards on the performance of firms (Frenz and Lambert 2012). The results are based on Quality Management Standards 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 Quality Assurance Register, which is the only available database listing awards to 9001:2008 from a range of UKAS accredited certification bodies.

Because of the form in which the data are compiled, the indicator used in the analysis 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 Quality Management Standards 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 Quality Management Standard as a platform for or enabler of innovation.

The ISO 9001 indicator is significantly correlated with innovation. Accredited certification intensity is correlated with investment in the creation of intangible assets. It is also significantly linked with a technology based innovation mode that involves the extensive use of Intellectual Property Rights (IPRs), 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. Quality Management Standards 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 strategic orientations of innovation.

There is a body of literature on the impact of certification to a quality management standard, largely in academic management journals. Most of the literature covering the areas of conformity assessment that are in the UKAS portfolio is concerned with certification, mostly against the ISO 9000 series of Quality Management Standards. Research in these topics has been facilitated by the ready availability of data on numbers of certificates issued, either from ISO itself or from national agencies. A selection of the studies are summarised below, including recent analysis for the case of the UK. But, it should be noted that the studies typically do not record whether the certificates are issues by accredited certifying bodies. It is, though, widely assumed in the certification community that the majority are, at least in the advanced economies. One exception is the UK study, which uses data from accredited certification bodies. This section briefly summarises a few of the papers, published in leading management journals, but without attempting an exhaustive coverage.

Sampaio, Saraiva and Rodrigues (2009) analyse data from the ISO survey of certificates to ISO 9000 collected by ISO on a two-yearly basis. The dataset goes up to 2004 and Sampaio et al. report a fairly steady growth in certificates from 1993, with some fluctuations. They state that: "According to the ISO Survey 2005, in December 2004 there were issued nearly 700,000 ISO 9000 certificates in the world, thus reflecting the huge importance that ISO 9000 certification has assumed for companies across the planet" (Sampaio et al. 2009: 1,303). This had grown to over 1 million by 2010.

The core of the paper is an attempt to relate indicators of national level economic performance, e.g. GDP, to the intensity of ISO 9000 usage. The paper reports on total numbers of certificates by country – led by China – and also on shares per capita of population and per number of firms with 10 or more employees. For the latter indicator, Italy records the highest level in 2004. The UK was world leader but is now in the middle group, with around 0.86 certificates per 1000 population. (Note that net inward migration will affect the shares normalised by population).

Sampaio et al. attempt some test of the association between the extent of certification and indicators of national economic performance. This is done simply by using the levels (current values) of indicators in 2004. They find weak positive link, and some evidence of a negative association between the number of certificates in a country and country performance. The statistical analyses are hampered by a lack of appropriate controls, variables other than ISO 9000 certificates, that explain country-level performance, and thus the results have to be treated with caution.

As the data runs from 1993 to 2004, some exploration of the trends in certification and economic growth or productivity might have been expected. An example of this sort of time series analysis is in Department for Trade and Industry's (DTI) Economics Paper 12, the Empirical Economics of Standards, which shows a well-defined statistical relationship between the evolution of the stock of standards and productivity growth (specifically Chapter 2 of the DTI report by Temple, Witt and Spencer, 2005). An important difference between the studies is that the DTI analysis by Temple et al. includes all standards, technical, environmental etc. as well as management, so summarising knowledge for production and innovation across a fuller range of and picking up some of the important complementarities between resources and capabilities.

Another contrast is with the Innovation Dynamics study, which found a positive link between accredited certification to ISO 9001 and innovation and productivity and growth indicators

for the UK (Frenz and Lambert, 2011). This model, too, includes other facets of innovation and efficiency in a multivariate model.

"According to Saraiva and Duarte (2003), the ISO 9000 certification market saturation level seems to be reached for values that range from 1.2 to 1.6 ISO 9000 certificates per 1000 inhabitants. In 2004, there were no countries in the ISO Survey with ISO 9000 scores higher than 1.6, confirming this empirical evidence" (Sampaio et al., 2009: 1,305).

Terlaak and King (2006) report on just below 20,000 US manufacturing plants/facilities and link longitudinal data – 1988 to 1999 – of ISO 9000 certification to a measure of competitive advantage. They find a positive association between competitive advantage, here proxied by the change in production volume before and after certification – and ISO 9000 certification, and suggest that this relationship is particularly strong in markets where there are greater information asymmetries between buyers and sellers.

Benner and Veloso (2008) in their study investigating the link between the use of ISO 9000 and firms' financial performance analyse survey data from the US automotive parts sector. This study concerns the evolution of the take up of ISO 9000. Benner and Veloso note that the promise of performance and efficiency from applying ISO 9000 has not always been realised, according to earlier research.

The underlying framework for the paper is that a standard for process management needs to be integrated with more firm specific competitive advantages for there to be a significant impact on firm performance. Otherwise the simple adoption of a universalising standard for management of the enterprise pushes it to similarity with other firms, not to find its own particular competitive advantage.

By using panel data, the study was able to take account of firm specificity, and to investigate whether early adopters experience a higher impact than those following later. The main conclusion on this research question was that later adopters did indeed show lower performance gains, which can be attributed to the spread of best practice widely in an industry, so that later adopters are less able to demonstrate improvement, against a rising norm.

It also took account of the degree of 'technological coherence'. This was to test the hypothesis that a central expected benefit of a process management standard is better integration of separate or sequential parts of a production system. So a firm with a narrow technology base has less to gain from process integration, while one with a very wide span of technologies would be less able to make them coherent, even with the application of ISO 9000. The study suggests that the ISO effect might even be negative, for firms with very low or very high coherence.

In summary, the study reports that early adopters did experience some performance improvements, though these varied with the performance indicator used. Later adopters, as the standard approached being normal behaviour in the industry, did not find such performance gains. It should be noted though that the performance indicators were relatively narrow – return on assets, return on sales and relative stock market valuation. But gains in efficiency might also be expected to be reflected in other, non-financial indicators, such as market share, or might accrue in part to other firms, through embodied improvements in quality or service or though demonstration effects.

The study also reports that the greatest benefits did indeed occur in firms with medium technological coherence. This confirms their broad hypothesis that the effects of application of ISO 9000 will depend on that nature and structure of the firm.

A conference paper by Nguyrn Thi and Martin (2010) uses Luxembourg data from the Community Innovation Survey 2006 and ISO 9000 certificates data for the same firms. Broadly it finds that certification interacts with other innovation elements positively but with instances of a negative relationship. The aim is to investigate the balance between the potentially fostering and hampering effects of standards on innovation at the same time.

The main conclusions that this paper makes are the following. First, ISO 9000 certification is positively and significantly associated with innovation if the measure of innovation includes organisational or marketing innovations. They find no such associations in the case of technological innovations per se. This seems broadly consistent with the results of the innovation dynamics project that found accredited certification to be supportive of, or an enabler of several types of, mixed modes or styles of innovation (Frenz and Lambert 2012). Second, the positive impact of management certification is stronger in the case of small firms compared with large ones (Nguyrn Thi and Martin 2010).

Martínez-Costa, Choi, Martínez and Martínez-Lorente (2009) compare the benefits of ISO 9001 certification to certification of the earlier standard ISO 9000 and non-certification using a sample of 713 Spanish manufacturing firms with 100 and more employees. They report no difference in performance using a composite indicator in an attempt to measure a latent performance concept.

Both the latter studies do not explore further the time dynamics, and as is the case for most studies that use cross-sectional data, attributing cause and effects is not practicable. It may be, for example, that better performing firms follow simultaneously innovation and certification in order to enhance their competitiveness and market leading positions.

4 Results

4.1 UKAS: estimating the size of the market

A major part of the UK quality infrastructure system, and with it the accreditation activities, rests with the testing and calibration laboratories that provide 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 billion. Over half of employment, and nearly 75% of turnover, is in 20 large businesses. Table 1 shows more detail on the sector.

Table 1 Size of the technical testing and analysis sector (SIC 712) in 2010

	Number of 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 Inter-Departmental Business Register data, 2010.

However, it should be noted that not all accredited conformity assessment bodies are in the sector as defined by the SIC code 712 – technical testing and analysis sector – while not all businesses in the sector are active in the technologies and industries covered by UKAS accredited standards.

4.2 Results from the UKAS/BMTA survey

4.2.1 The survey data

This section presents findings from what this report refers to as the UKAS/BMTA survey, which was conducted specifically for the purpose of this study. Members of the British Measurement and Testing Association (BMTA) and UKAS customers, were approached with a short questionnaire. Responses from 176 firms were collected in July 2012. UKAS and the researchers are very grateful to the people and organisations who completed the questionnaire.

First, this section describes the questionnaire design, sampling method and sample sizes, before presenting results on the value of accreditation to the respondents. Where appropriate this section also discusses and analyses survey data collected by the International Accreditation Forum (IAF) in 2011. We refer to this survey as the IAF survey.

The UKAS/BMTA questionnaire is short, containing nine questions. A copy of the questionnaire is in Appendix A. During the question development we were advised by experts based in the British Measurement and Testing Association (BMTA) – Peter Russell and Jeff Llewellyn – as well as Malcolm Hynd from UKAS. Initially, a pilot version of the questionnaire was emailed to all BMTA members. Following minor edits to the questionnaire, this was then send to all UKAS private sector customers.

The first section of the questionnaire asks businesses about their main activities, the size of the organisations measured in four size-bands based on their number of employees, and whether or not the businesses was an accredited service supplier and/or user. Subsequent sections asked for the share of services purchased and sold across a range of activities, such as calibration, testing or certification that are accredited. The questionnaire explores the price premium, if any, of accredited services; and the importance of accreditation to responding businesses. The final two questions are open ended, inviting respondents to comment on (a) the main benefits of accreditation to their business, and (b) to quantify the economic value of accreditation.

Data was collected on-line using survey website (www.surveymonkey.net). Additionally, a word version of the questionnaire was emailed to businesses which only a very small share preferred to use. In total 176 responses were received. This survey has been invaluable in providing a broader picture of the market for accredited services, and as will be seen, enables some statistical analyses and inferences to be drawn. The survey is not statistically representative, but replies have come from across the range of accredited service suppliers and users in proportions that are not wholly out of line with the numbers of UKAS customers in each of the service areas. So we feel confident that the data can be used to provide indicators of important facets of the markets for services, and the role of UKAS accreditation in them. The following tables summarise the responses to the survey.

Table 2 Size distribution of businesses in the UKAS/BMTA survey

Size-band	*Number of businesses*	*Percent of businesses*
Less than 10 employees	32	18
10 to 49 employees	64	36
50 to 249 employees	34	19
250 and more employees	46	26
Total	**176**	**100**

Source: UKAS/BMTA survey own calculations. Analysis of question 2.

The responses are skewed towards large and medium sized businesses which are over-represented. However, the patterns of responses to the subsequent question do not show large variation between size groups and there are some off-setting advantages of this distribution in that the sample includes a larger share of industry employment and sales.

Table 3 Main activity of businesses in the UKAS/BMTA survey

Main activities	*Frequencies*	*Percent*
Calibration	48	27
Testing	121	69
Certification	22	13
Inspection	28	16
Manufacturing	20	11
Other main activity	10	6
All businesses	**176**	**100**

Source: UKAS/BMTA survey own calculations. Analysis of question 1.

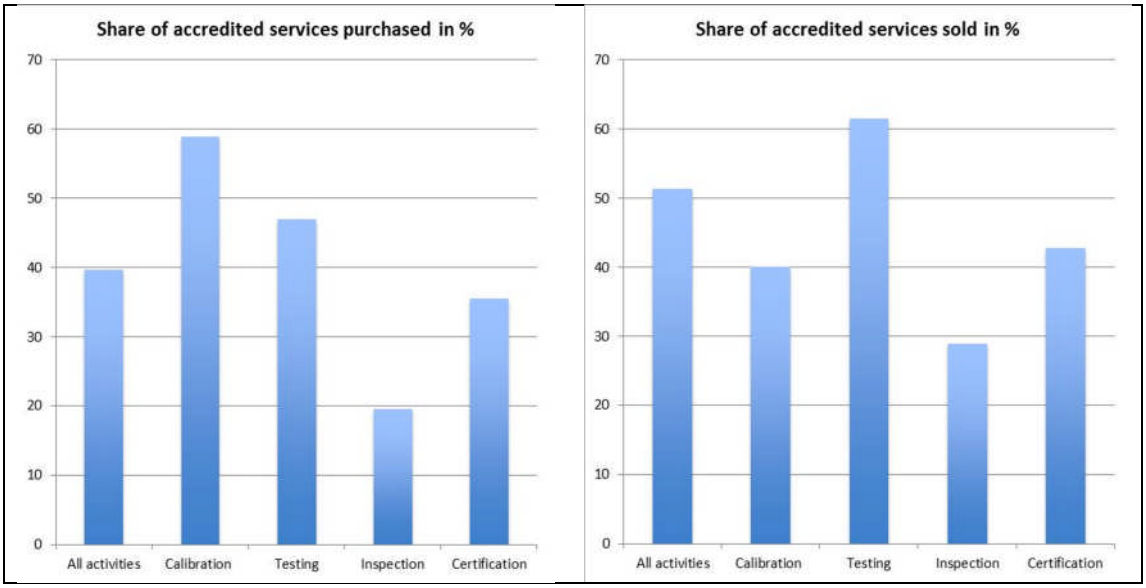
Just under 70% of businesses' main activity is testing, followed by 27% in calibration, 16% inspection and 13% certification. There are also 11% of responses from manufacturing firms that provide accredited services through in-house laboratories. Imaging services and medical laboratories only returned one reply each (not reported in the table above) and are excluded from analyses into the value of accreditation when we report figures according to the type of main activities. The majority of accredited medical laboratories did not receive the invitation to participate in the survey.

The IAF survey was sent to customers of product certification bodies, and quality- and environmental management system certification bodies. Thus, the survey does not cover technical standards, but explores management system certification only. We analyse parts of the firm level responses from 201 UK businesses that completed the IAF survey in 2010 in this chapter later on, after a more detailed discussion of the UKAS/BMTA survey.

4.2.2 Share of accredited services

One of our first questions is designed to establish the extent to which accreditation is used for different services. Our results suggest that around 50% of services sales are accredited.

Figure 1 Share of accredited services purchased and sold



The bars are the share of accredited services purchased and sold as a percentage of total services purchased and sold. *Source*: UKAS/BMTA survey own calculations. Analysis of question 4.

The highest accredited share sold is in testing, with 62% of service sales accredited. Calibration services report the highest accredited purchased share at 59%. Calibration is an important input into most testing activities, and, thus, a logical flow might be expected from calibration purchases to testing sales within the survey.[1]

[1] We are grateful to Graham Torr from the National Physical Laboratory for making this observation.

The accredited shares of Inspection services are the lowest, (20% among services purchased and 29% among services sold). This may be attributable to a relatively low rate of amongst the large number of small businesses in Asbestos surveying.

With respect to certification the IAF survey reports much higher shares of accredited certification used. 88% of IAF responses reported that certificates were issued by accredited bodies, compared with 36% of certificates bought in the UKAS/BMTA survey. It is possible for businesses to self-certify to a Quality Management Standard and there are also a numner of bodies certifying compliance with ISO 9001 who do not have accreditation.

4.2.3 Perceived importance of accreditation

This section reports on the importance of accreditation. Firstly, out of all UKAS/BMTA responses 82% rated accreditation of high importance to the business and 15% of medium importance. Only one, large, business out of 176 businesses considered accreditation as not relevant. and one explanation might be that accredited services form only a small part of that business. Similarly, from the IAF survey 81% of responses rated accreditation as essential or very important and a further 5% as fairly important.

On average, accreditation seems to be of greatest importance to medium sized firms (88 % high importance), followed by small firms (86 % high importance), micro firms (81 % high importance. Among large firms about three quarters rated accreditation highly important to their business. Figure 2 reports on the importance of accreditation for different types of services providers.

Figure 2 Importance of accreditation by main activity

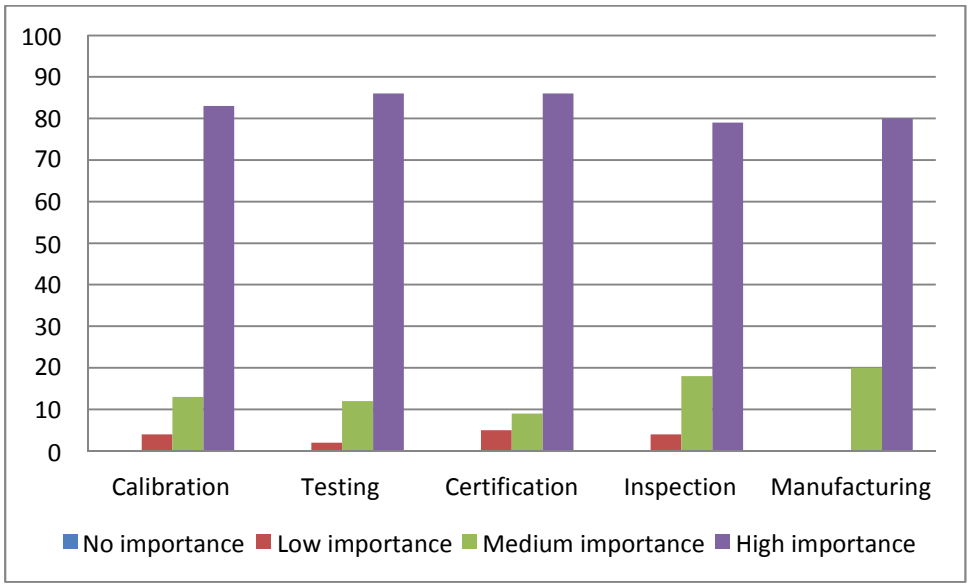


Figure reports the percentages of businesses that rated accreditation of high importance, medium importance, low importance or of no importance. *Source*: UKAS/BMTA survey own calculations, based on cross-tabulation of question 7 and question 1.

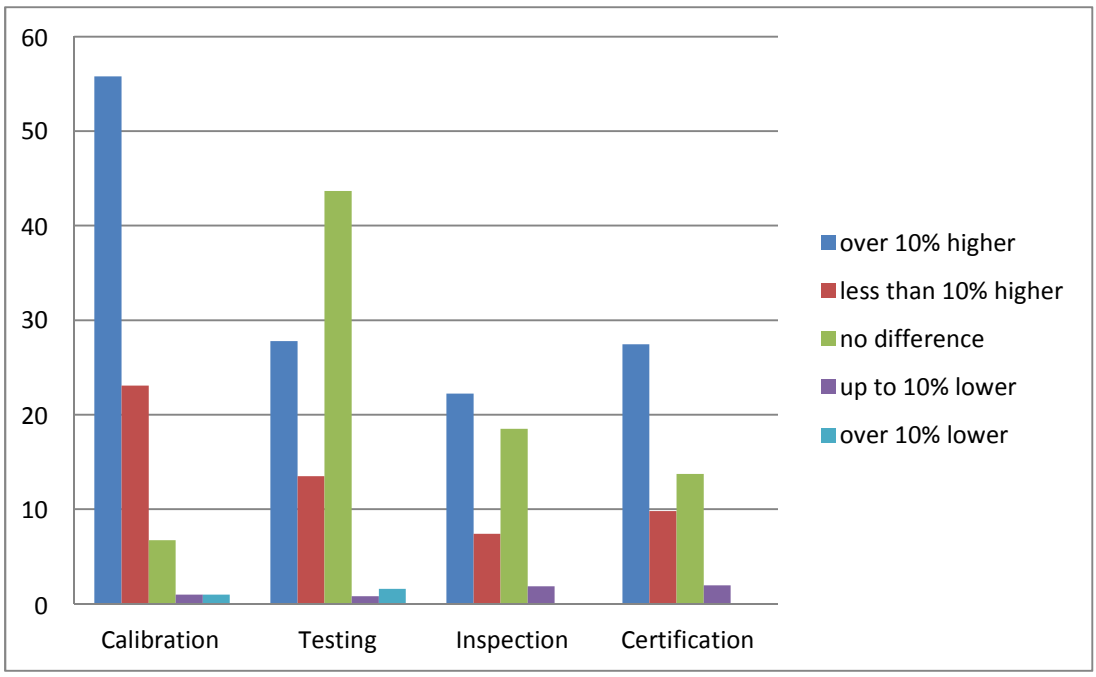
Just over 80% of all respondents rated accreditation as highly important to their business activities. Testing labs and certification bodies report the highest figures (86%), inspection bodies the lowest (79%). Inspection might include less sophisticated methods, for example, the visual inspection of scaffolding, compared with activates carried out by testing labs to

determine the characteristics of a specific product, for example, the testing of a satellite antenna (Guasch et al 2007).

4.2.4 Price premia and willingness to pay for accreditated services

In the next section we look at the price premia for different services (a) with respect to users and (b) providers of accredited services. This is, as far as we know, a new contribution to knowledge on the operations of accredited services.

Figure 3 Price premia of service suppliers for accredited services



Percentage of service providers that estimated their price of accredited services as: over 10% higher, less than 10% higher, no difference, up to 10% lower, over 10% lower. *Source*: UKAS/BMTA survey own calculations based on cross-tabulation of question 5 and question 3.

The majority of businesses reported a significantly higher level of charges (e.g. 57% of calibration labs reported over 10% higher charges) or no difference in prices (e.g. 53% of testing labs reported no difference in their prices of accredited vs. non-accredited services). A very small number of respondents report that prices for accredited services are lower (two testing, two calibration, one inspection and one certification body). The bars in the figure above do not add up to 100%. This is because some businesses did not answer this question: 12% in calibration, 11% in testing, 48% in inspection and 44% in certification.

The share reporting a substantial price premium is particularly high for calibration services, where accreditation is seen as highly important and to account for the majority of the market. Accreditation price premia were reported by lower shares of respondents in the case of inspection and certification services, but these also showed a majority who did not answer the question on relative prices. Of those who answered the question, a substantial majority reported a significant price premium for accreditation in each type of service.

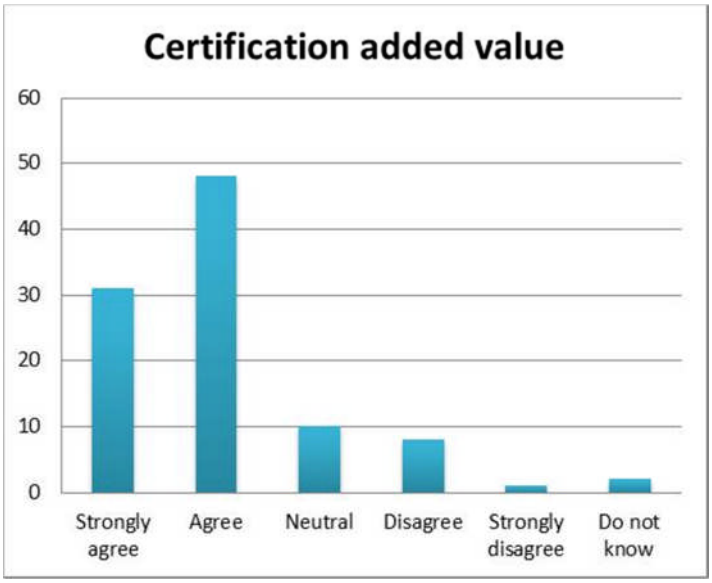
Some of the interview evidence can extend these insights into the operation of the market. Very small and start-up firms indicated that competition left them unable to command a

higher price for their accredited services, although there were costs of acquiring and maintaining accreditation from UKAS and additional costs, for example in specialised equipment, incurred in offering a service to the specified standard. The gains from accreditation to them came through improving their own processes to meet the requirements of accreditation and from increased market acceptance arising form the indicator of quality. This is borne out by responses to other topics from the survey, summarised below.

4.2.5 IAF Survey – certification impacts

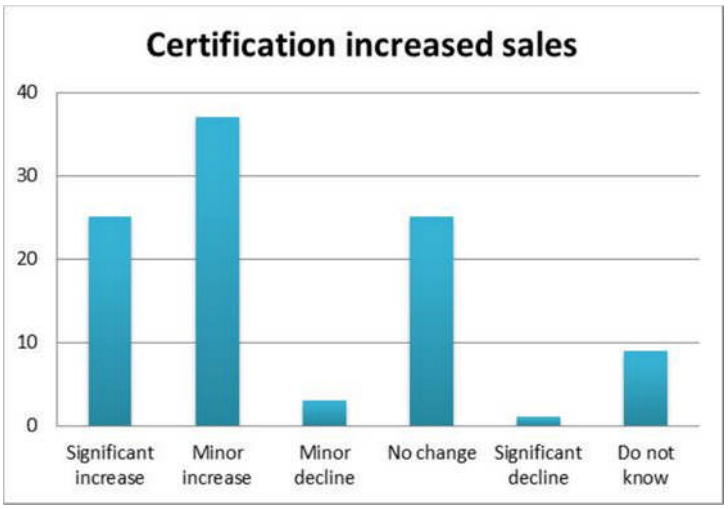
This section examines two questions in the IAF survey: (i) "in your opinion, has certification added value to your organisation?" and (ii) "has certification led to a difference in sales?"

Figure 4 Rating of the value of Certification



Share of businesses that agreed (or disagreed) with the statement that certification added value to their organization. 142 businesses replied to this question. *Source:* IAF survey own calculations.

Figure 5 Sales increases from certification



Share of businesses that associated an increase (decrease) of sales with certification. 142 businesses replied to this question. *Source:* IAF survey own calculations.

The majority of firms agreed that certification added value to their organisation and increased sales (79% and 62% respectively). In part these benefits might be due to the auditing process, the implementation of new processes, the learning associated with it and the signalling it does for the clients of the respondents. The majority of certificates in this survey are accredited certificates. But, from the table above it is not possible to distinguish between the contribution of certification process per se and the added assurance gained through accreditation.

4.2.6 Reported main benefits of accreditation

In the UKAS/BMTA survey we asked firms to specify the main benefits of accreditation to their business using an open-ended question. Recoding responses into benefits categories or themes, we find that the most frequently occurring benefits are associated with marketing and communication and the reputation of the business. Most firms in the industry face competitive market places and the external validation through accreditation adds value to their organisations and their market offerings.

These results confirm the impression from interviews, that for most businesses, the advantages of gaining accreditation are commercial, and do not derive from a regulatory requirement. For a large proportion of the market, some of these commercial benefits take the form of a higher level of prices, reflecting the costs of gaining accreditation, and the assurance of quality that it represents. In other cases, the commercial benefits seem to be manifest more in gaining market share, or in responding to a direct customer requirement.

Figure 6 Main Benefits from use of accredited services

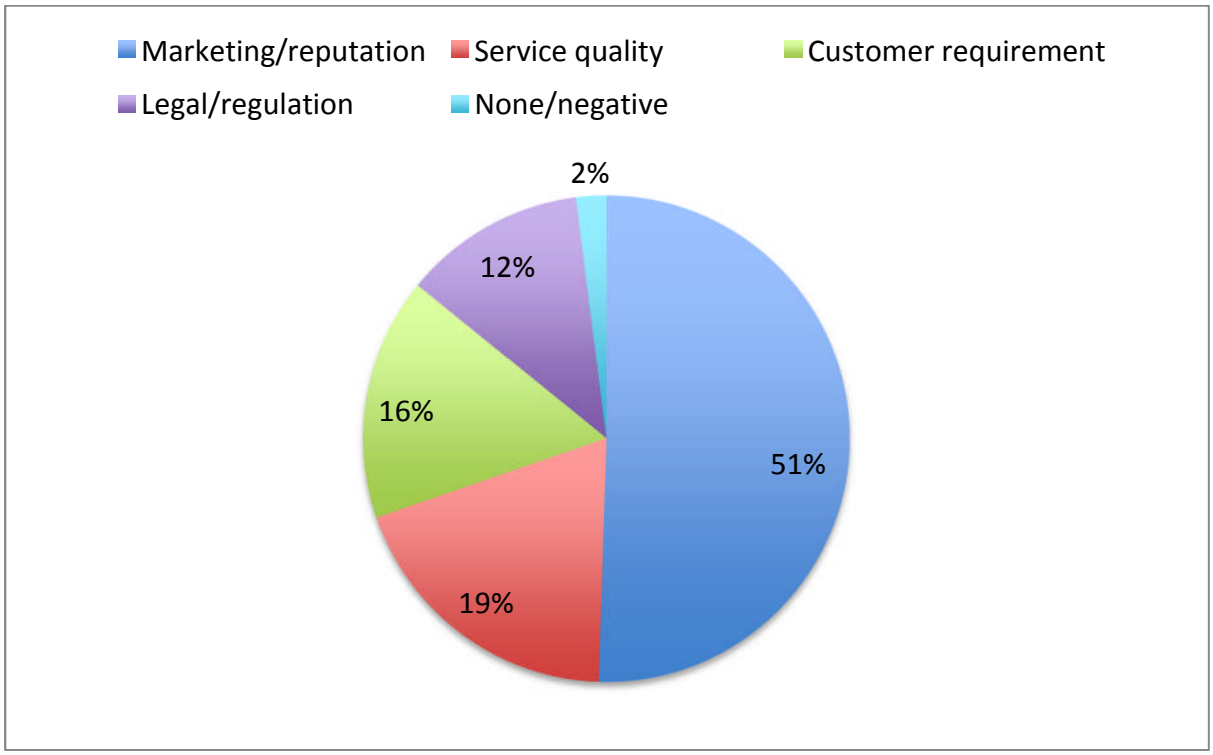


Figure reports percentages of businesses that described their main benefits of accreditation to fall into the categories/themes of: marketing/reputation; service quality; customer requirement; legal/regulation; and none or negative. Percentages are based on 155 survey replies. *Source*: UKAS/BMTA survey: question 7.

There are also important learning and efficiency enhancing effects from the processes of assessment for accreditation. Our interviews indicated that even large service suppliers, who have the option of relying on their own reputation, find accreditation by UKAS confirms and enhances that reputation, and that they were able to make gains in efficiency for example in staff management and training, as a result of undertaking the UKAS assessment.

These results reported in this section are consistent with findings from a survey of UKAS customers carried out in 2005 by Databuild on behalf of UKAS (Databuild Report, 2005).

5 Estimating the economic impact of different channels of the quality infrastructure

One of the important objectives of this report is to arrive at estimates of the 'impact' or 'value added' to the economy of the UKAS accreditation system, which is quite difficult both conceptually and empirically, given the limited amount of theoretical guidance and specific data.

In Section 2 above, we have outlined what accreditation offers, which may be summarised in some propositions that can in turn serve as a guide to the estimation of economic value in the UK business sector. Accreditation also generates value in **public services**, including health care and through the promotion of **international trade**. These are covered in later sections.

Value propositions:

- A degree of assurance of reliability of the service provider, whose technical and organisational competence and processes have been independently assessed.
- In many cases a more rigorous and so higher cost service, for example, a more complete calibration process or testing to a specific and demanding degree of accuracy.

Accreditation is embedded in the activities of businesses providing services that have been assessed by UKAS and it is difficult to identify its effects in the wider economic system. But the scope of accreditation varies between businesses and many offer both accredited and non-accredited versions of the same basic service, while other service providers may have no accreditation at all. The market is willing to buy similar services with and without accreditation, which provides a basis for an approach to one element of the economic benefits of accreditation – the market value of UKAS accreditation supported services.

5.1 Willingness to pay

In a subsequent section, we explore the impacts of accredited services on efficiency and innovation, and, thus, on growth and productivity. But in this section, we explore the approach, through the market value of accredited services, using information from the survey of UKAS stakeholders and BMTA members. The extent to which market prices for services are higher for the accredited version, which we interpret as the 'willingness to pay' for what accreditation of the service provider to an exogenous standard offers.

The achieved price premium for an accredited service reflects in part the value that customers place on these factors, as well as the value of the assurance of reliability of the service that accreditation also provides. An empirical problem, though, is the absence of good data on the overall values of the markets for the relevant services. For the estimation of the value of accreditation reported here, we have used a variety of sources of information.

Firstly, the number of businesses holding UKAS accreditation for the provision of the services is set out in Table 4.

Table 4 Number of businesses with accreditation

Service	*Number Accredited*
Testing	1,145
Calibration	345
Certification	177
Inspection	299

Source: Data provided by UKAS.

These figures are of accredited business entities. Some large businesses have several accredited units, while a business is listed as accredited if one of its services is so. It may also sell some or the majority of its services without accreditation. There are also over 900 accredited pathology testing labs. But their position in the public health service suggests that attributing a market value to accredited status is particularly problematic, so the nature of benefits from the role of accreditation in public services, and health in particular, is considered in a separate section.

The UKAS/BMTA survey gives an estimate of the share of sales or purchases of these services that are accredited. In their study of 2005, Databuild reported that the majority of the use of these services (or at least the majority of business) was of the accredited form. The new survey does not bear this out, rather indicating that the shares covered by accreditation are up to around 50% in calibration and testing, around 40% for management systems certification and 25% for inspection of equipment and installation (based on responses to question 5 in the UKAS/BMTA survey). Some calibration service providers we spoke to took the view that a minority of their market is covered by accreditation. We cannot tell from the survey whether the non-accredited share is mostly supplied by non-accredited businesses or by those with some scope of accreditation.

In order to arrive at a market value for these services we need an idea of the value of the markets for each. There is a lack of market intelligence on these specialised sectors, so we have used indirect indicators derived from data on sales and employment from official statistics on the 'Technical Testing and Analysis' industry (SIC (2007) code 712). Not all enterprises supplying the relevant services will be included in this SIC code. Some units, for example, are part of larger enterprises classified to another manufacturing or service code. Similarly, the industry defined by SIC 712 will include testing and analysis activities not covered by the standards and accreditation system – vehicle testing for example. Nor is the industry thus defined disaggregated into calibration, testing, inspection and so on. Nonetheless, this SIC code provides the most useful indicators of the testing, calibration, and inspection sectors.

Table 5 Structure and size of the technical testing and analysis sector in the UK in 2010

	Number of 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 Inter-Departmental Business Register data.

As a working assumption, we have adopted the mean value of turnover per enterprise as 'representative' of the ranges of businesses in the UKAS accredited family. This is calculated as £2.9m per business. This is obviously a very broad brush measure, and we use it here to provide working figures for the purpose of an indicative 'market value' for the assurance of reliability that accreditation provides for final customers. The turnover of UKAS accredited businesses is then:

Table 6 Turnover of UKAS accredited businesses

Accredited	*Number of businesses*	*Average turnover in £m*	*Total turnover in £m*
Testing	1,145	2.9	3,320
Calibration	345	2.9	1,000
Certification	177	2.9	513
Inspection	299	2.9	867

Source: Own estimates based on information from UKAS and the Inter-Departmental Business Register.

The survey results indicate that, on average, prices for accredited services are higher. The survey results are in ranges but numeric values can be imputed by assuming that: the 'over 10%' premium is on average 15%[2]; the 0-10% premium is on average 5%, and, similarly, when accredited service prices that are lower are reported.

On these assumptions the average price premia from the survey are:

- Testing 6%
- Calibration 11%
- Certification 8%
- Inspection 7%

Taking account of the shares of service sales that are reported to be covered by accreditation (broadly 50% in testing and calibration, 40% in certification and 25% in inspection), these price premia imply the following values of 'willingness to pay' for accreditation, totalling £200m.

- Testing £100m
- Calibration £60m
- Certification £20m
- Inspection £20m

5.2 Producer and customer surplus

The 'willingness to pay' through a higher price for an accredited service outlined above is one form of a more general economic impact known as a 'surplus'. This is in essence the difference between the amount paid for a good or service and the value to the user and can accrue either to the suppliers or the customers. In cases such as accreditation, that serve to

[2] This is a conservative judgment, implying a range of premia of between 10 and 20%. An alternative assumption is that the range above 10% is 10 to 30%, with a mid-point of 20%. The overall distribution of the price premia for the majority of services suggests that it would be difficult to substantiate a much higher representative premium.

raise service quality, there will be other elements of surplus value, even in cases where, e.g. due to competition or other factors, the quality difference is not reflected in prices. The paragraphs that follow set out how these surpluses arise and make indicative estimates of their possible scale.

As predicted from the characteristics of accreditation in the quality infrastructure, outlined above, the process of external assessment of conformity with a standard can involve the transfer of knowledge, e.g. of best practices, into the assessed business. The results from the UKAS/BMTA survey confirm the impression of experts and statements from interviews that there are internal learning benefits from the review and the need to meet the criteria for validation. Around 19% of respondents reported that improvements in the quality of service were the major benefit of accreditation. These may translate into lower costs, and hence higher margins for the service providers, or into an enhanced quality of service for customers that may not be reflected in a higher price. An approximate indicator of the value of these quality of service benefits can be derived by assuming that they are of the same order of magnitude at firm level as the price premium for those who report those benefits.

From the UKAS/BMTA survey also, some 50% of respondents reported that the main benefit of accreditation lies in marketing or reputation benefits, which are likely to result in a higher market share than would otherwise be the case – a producer surplus, or in a better quality of service for users – customer surplus. But this may not be manifest in a higher price. These elements of surplus value can also be computed from the survey data on the – very sweeping – assumption that the higher prices when realised reflect real differences in supplier costs and customer advantage and can thus be used as a 'proxy' for quality difference.

The application of this analysis to the proportions of the market for each service that report these main benefits but zero or negative price premium leads to a rough estimate of additional surplus value from efficiencies and quality of service of some £25m. Together with the 'willingness to pay' directly for accredited services of £200m, calculated in the previous section, our central estimate of the commercial benefits from accreditation, conservatively estimated, is some £225m. To put this in context, UKAS turnover is around £20m, so that a benefit to cost ratio of around 10:1 is indicated, without taking account of the downstream effects of economic performance arising from the use of accredited services, which is the subject of the next section.

5.3 The quality infrastructure and its link with innovation and economic performance

The previous section has presented some estimates of one dimension of the economic value derived from the UKAS accreditation service: the willingness of users to pay a higher price for accredited services. This is only one part, and likely to be only a small part, of the economic benefits generated by an independent accreditation body. As outlined in the introduction to this report, accreditation is in a sense the keystone of the quality infrastructure, and the economic impacts of that infrastructure have been shown to be large in numerous studies for several different countries (e.g. Gonçalves and Peuckert, 2011).

In this section, we summarise the results of a particular economic model that shows how the elements of the quality infrastructure, directly and as support for innovation, have impacts on economic performance indicators (based on Frenz and Lambert, 2012). The model is based

on a typology of innovation derived from the extensive data available from successive UK Innovation Surveys.

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

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

Modes can be thought of as the underlying process of innovation, a bundle of activities done in tandem by firms, and whose working 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. A description of the statistical computation of the modes is in Appendix B.

The mixed modes of innovation model used in this report includes indicators of the role and importance of the quality infrastructure at two levels of analysis: (a) the firm level obtained from the UK Innovation Survey and (b) evidence external to the survey measured at a higher level of aggregation (in this case at the level of the industry or geographical location). The use of standards as a source of information 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 9001 – observed at county-level. Further information on the data sources and compositions of the Innovation Survey external data are in Appendix C. The table below summarises the six mixed modes of innovation by providing the survey items that underpin each mode.

Table 7 Mixed modes of innovation

Innovation mode	*Activities underpinning the innovation mode*
IP technological. innovating	Use of patents, registered design and copyrights. In-house R&D.
Investing in intangibles	Internal R&D, bought-in R&D and knowledge, machinery and equipment purchases, training, design and marketing of new products
Using codified knowledge	Use of standards, publications and information from businesses and universities. Cooperation on innovation.
Wider innovating	New strategy, management technique or organizational structure. New marketing strategy.
Market-led innovating	Introduction of a new product, marketing expenditures
External process modernizing	External innovating. Introduction of a new production process or service delivery method

Source: based on Frenz and Lambert (2012).

The mode interpreted as firms investing in intangible investment groups together the propensity to invest in the creation of knowledge assets: R&D, advanced machinery and IT, training (raising human capital) and marketing. 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.

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. When the modes are compiled with earlier instances of the UK Innovation Survey that includes 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.

Two other components of the quality infrastructure, measurement and certification of management systems, are not included as lines of questioning in the surveys, but can be represented from external sources at a higher level of aggregation, either industrial sector or varying by 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 intensity of take up of management certification. The next table summarises the findings of twelve regressions. The full results are in Appendix C.

Table 8 Correlations between innovation modes, measurement knowledge and quality management certification

	IP/techn. innovating	Investing in intangibles	Using codified knowledge
Measurement knowledge	-**	+***	+*
Stock of standards		+*	
Instrument purchases		+**	
Quality management certification	+*	+**	+***

	Wider innovating	Market-led innovating	External process modernizing
Measurement knowledge		+***	+**
Stock of standards		+***	
Instrument purchases		+***	
Quality management certification			

*** = correlations significant at 1%
** = correlations significant at 5%
* = correlations significant at 10%

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. In his paper for the 'Empirical Economics of Standards' report to the Department of Trade and Industry, Peter Swann reported that the propensity to see standards as a source of information for innovation was weakly correlated with the size of the stock of standards relevant to an industry (Swann, 2005).

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 the independent evidence that the public research base is intertwined with the measurement system, for example through joint research and publications, and through research and teaching institutes' use of measurement standards and expertise. This mode is also intensive in other forms of 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.

For quality management certification the indicator used 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 possible effects of Quality Management Standard 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. As the data are supplied by accredited bodies, we assume that all the certificates covered by the variable are accredited, so the comparison of performance is with those firms either with no certification, self-certification or a certificate issued by a non-accredited certifying body. Around 8% of UK firms are thought to be certified (expert comment during interviews) so that the significance of the accredited certification variable is striking. 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. So an association between ISO 9001 and innovation indicators is a pointer to the role of accredited certification to a Quality Management 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. Certification intensity is correlated with an innovation strategy through investment in the creation of intangible assets. It is also significantly linked with a technology based modes that involves the extensive use of IPRs, in conjunction with technology development, which implies that certified 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.

As well as acting as supporting factors to the styles of innovation summarised in the mixed modes indicators, the exogenous quality infrastructure variables for measurement and QMS are used as explanatory variables in equations estimating productivity levels or changes, or growth in output and employment. The table below summarises findings from twelve regression models that are reported in full in Appendix C.

Table 9 Summary of findings from the econometric analysis

	Productivity	Change in productivity	Change in turnover	Change in employment
Measurement knowledge	***	***		
Stock of standards	***	**		
Instrument purchases	**			
Quality management cert.		**	**	*
Using codified knowledge	***	**	*	
IP / techn. innovating	***		*	
Investing in intangibles				
Market-led innovating				
Wider innovating			***	**
External process modernizing				

See Appendix C for full results.
*** = correlations significant at 1%
** = correlations significant at 5%
* = correlations significant at 10%

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.

The exogenous variables based on measurement knowledge and ISO 9001 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.
- ISO 9001 certification shows impact on growth, suggesting that sound management structures and practices, tested and approved to relevant standards, lay the foundation for good business performance and economic benefits.

As well as exploring the broadly contemporaneous relationships between economic performance, the innovation modes and the exogenous indicators of measurement and accreditation, the availability of the panel data from the innovation survey enables these relationships to be investigated over time, allowing for the longer-term impacts of the infrastructure.

The codified knowledge mode includes standards together with the public research base, and is supported by Quality Management Standards certification. 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 accredited Quality Management Standards certification. 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 business development and growth.

Measurement and accredited certification to a Quality Management Standard also correlate with performance beyond the innovation mechanism, potentially enabling or supporting growth and productivity in their own right. These multiple routes to impact are a reminder that the quality infrastructure is widely specified and accessible to all firms and industries, one of the elements in the rationales for public support or validation of the provision of these types of valuable knowledge and the institutions that provide or enable their use.

UKAS accredited testing and calibration labs are the backbone of the National Measurement System, ensuring the traceability of tests and calibrations to the international standards held, in the UK, by the National Measurement Institutions. So, the significant relationship between the indicator of measurement intensity at sector-level, and the modes of innovation, and levels and changes over time of productivity and growth in sales is substantially underpinned and enabled by UKAS accreditation. The economic value of this underpinning cannot be directly calculated from the results presented here. The metrology indicator is measured on a relative scale at sector level. So that sectors exhibiting higher metrology intensity show on average better economic performance. The role of accreditation, the additional value in use of accredited services, can be expected to apply at all levels of metrology use.

5.4 Quantifying the impact of accreditation

It is possible, in principle, to seek estimates or indicators for the impacts of the quality infrastructure as outlined in the Swann model discussed above, and of the specific 'UKAS multipliers', to help with the problem of finding the value added of UKAS accreditation. As we have noted in the introduction, accreditation has not been the subject of much empirical research, so there are few, if any, indicators available from published sources. Some recent studies do, though, provide sources for the quality infrastructure impact, though not always taking account explicitly of accreditation. These include:

- Studies of the use by businesses of the National Measurement System, sponsored by the Measurement Institutions;
- Economic research on the role of standards in economic performance, sponsored by DTI;
- Economic models of the role of the innovation infrastructure, including, to some extent, the quality institutions and UKAS, carried out by the authors of this report on behalf of the Infrastructure Partners group;
- A survey, carried out as part of this study, of members of the BMTA and of UKAS customers, on the importance and value to them of UKAS accreditation. This survey has provided completely new and vital data on the economic value of accreditation and in its absence very little quantification of impact would be possible.

In this section we attempt some speculative estimates of the components of the value added of UKAS accreditation, utilising the available evidence.

The UKAS/BMTA survey sought an indication of the financial value to the business of accredited status (question 8 of the survey: "Can you quantify the economic value of accreditation to your business? If so, please provide a figure."). Some 15% of respondents provided a useable estimate, and the reported values are very widely distributed, with a standard error three times the mean. This suggests that the mean is not the appropriate indicator of central value and that the median value should be applied.[3] It is possible to extrapolate from these estimates of financial value on the heroic assumption that these responses, on a per capita employment basis, are representative of the accredited conformity assessment market. With such a small and non-representative sample, such an extrapolation can be at best broadly indicative of possible orders of magnitude. On this basis, the reported value of accreditation, scaled to the share of employment in the technical testing and analysis sector taken to be in accredited suppliers, is some £70m. This might be rationalised as the additional sales arising from accredited status, at prevailing market prices, and, therefore, separate from, and additional to, the 'willingness to pay' summarised above.

A survey of a sample of NPL customers, carried out by Databuild in early 2012, obtained estimates of the financial benefits – in terms of increases in sales or higher margins – derived by customers from their use of NPL services to support measurement based innovation, amounted to £634 m in 2011. This is the mid-point of a range from £567m to £701m.

[3] This is standard statistical practice when the distribution of observations does not approximate to the normal distribution. In this case, the median value is also the mode (most frequently occurring) further confirming that this is the most suitable single number measure of the distribution.

These benefits derive from the take up by both private sector businesses, and by the public sector, of the following NPL outputs:

- Collaboration
- Publications and downloads
- The measurement network
- Events
- Measurement services, including calibration, consultancy and knowledge sales.
- Training

It is reasonable to suppose that only a subset of NPL services are materially affected by accreditation and that others rest on NPL specific capabilities and assets such as research, expertise and the custody of the measurement standards. In what follows, we have assumed that calibration and related measurement services and training are supported by UKAS accreditation. Although NPL's supply of training services may not be directly accredited, we have assumed that the learning effects on the training of NPL's own staff arising from the process of UKAS assessment of calibration and other measurement services carries over into the quality and organisation of NPL's training offering. This type of spillover effect was confirmed in our interviews with large service suppliers. From data in the survey on the numbers of customers using each NPL services, we can calculate that around 25% of the financial benefits are associated with calibration and related measurement services and training. Here we have assumed a common average unit level of benefit from each type of NPL service.

A further key assumption is that the 'marginal effect' or UKAS multiplier of accreditation can be represented by the average price premium on accredited services, derived from the UKAS/BMTA survey. This has been calculated as 8%. We can also calculate from the analysis of customers by business size in the Databuild report, the sum of employment in the NPL customer base. By applying these assumptions, we can estimate a very indicative value added for UKAS accreditation as a modifier of NPL's services of around £20 per person employed in the customers.

For the present study, the issue then arises of how far the NPL results and the inferred UKAS factor in them - can be scaled to the overall market for quality infrastructure services. To make such calculations, we have had to make some broad assumptions. These are as follows.

The survey report included a sectoral analysis of the NPL customer base, which is dominated by manufacturing, business services and, to a lesser extent, the NHS. We have assumed that this breakdown is representative of the market for most conformity assessed services. We have further assumed, somewhat heroically, that all organisations in these sectors are affected directly or indirectly by conformity assessed services, so that the indicative value per capita of £20 for UKAS accreditation derived from the NPL data can be applied to total employment in these sectors. (While this may err on the side of over-estimation, as some sub-sectors and businesses may not be impinged by conformity assessment, we have excluded, due to lack of data, other sectors where some use of conformity assessed services is likely).

The NPL services assumed to be UKAS relevant include training, calibration and related consultancy, and it seems reasonable to suppose that at least the major suppliers of calibration can also offer training, advice and consultancy, so that the overall indicative unit value can be

used. Our estimate for the value added of UKAS accreditation of calibration and related services is then some £60m.

Further the NPL customer survey data covers calibration and related services, but not testing, inspection and certification. In order to estimate broadly indicative value added of UKAS accreditation across the full range of services, we have further assumed, even more heroically, that the calibration and associated services unit values can be used for testing and inspection and that these largely apply to the same economic sectors. To allow for the differences in sizes of the markets for testing and inspection, and, therefore, for the variation in 'reach' of UKAS accreditation via these services, the implied valuations of UKAS accreditation at the unit level are re-scaled by the ratio of accredited sales of these services to the accredited sales of calibration services. That is, the level of accredited calibration sales is taken as the benchmark. This gives an estimated value added of accreditation of £200m in testing and £20m in inspection.

Certification has been treated somewhat differently. Certification to management standards is potentially relevant to all sectors, but only around 18% of relevant UK businesses (assumed to be those with 10 or more employees) are externally certified by accredited bodies. This gives a UKAS value added for certification of some £40m.

The end result of this series of calculation is very indicative estimates of the value of UKAS accreditation on business financial performance, via calibration, testing, inspection and certification as shown, in round figures, in the table below:

Table 10 Estimated benefits of accreditation to service users

Accredited Service	*Estimate £m*
Testing	200
Calibration	60
Certification	40
Inspection	20
Total	**320**

Source: own broad estimations based on data from the Databuild study of NPL customers and the UKAS/BMTA survey.

These values, which have to be read with appropriate caveats in mind, are additional to the 'willingness to pay' value of £225m calculated in the previous section (p36)and to the estimate of commercial gain to service suppliers of around £70m based on reported financial benefit (p42). So the quantifiable economic value added of UKAS accreditation can be indicatively estimated at around £600m.

Because of the sweeping assumptions that have had to be made to enable estimation, these figures should be viewed as only broad orders of magnitude. But, as they are at least rooted in some quite extensive survey data, they are not wholly speculative. It seems reasonably safe to say that that commercial value added of UKAS accreditation of these services is of the order of several hundred million pounds, rather than of the order of tens of millions or billions. And these value added results do not represent the totality of the impact of UKAS accreditation. The following sections outline other routes to economic and social value and in most of the cases we lack any sort of data to permit quantification.

It is an attractive idea to use the estimates of 'impact' of measurement and standards in the innovation dynamics model outlined above, as a route to the contribution of accreditation to economic performance. Unfortunately, this cannot be achieved directly because of differences in the dimensions of the indicators. We have conducted some 'thought experiments' to identify the scale of the contribution that could be attributed to the multiplier effect of UKAS accreditation in hypothetical circumstances of a generally higher level of measurement intensity across industry and commerce. The results of this experiment are orders of magnitude for the UKAS effect similar to those derived above.

6 Other channels of impact

In this section we explore additional areas of support functions of the quality infrastructure that we have no data on.

6.1 International Trade

There is empirical evidence that standards promote trade (for a review see, for example, Gonçalves and Peuckert, 2011; for UK specific results, see Swann, Temple and Shurmer, 1996). 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 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." (UKAS website).

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.

Quality infrastructure & trade
Accreditation supports the effectiveness of the quality infrastructure in international trade, similarly to its role in the domestic economy. Through a system of mutual recognition agreements (MRAs), the calibration and testing facilities in a country that have been assessed by a recognised accreditation body can have their inspection certificates accepted as valid in trading partners. Without this framework of recognition, adoption of an ISO standard for a product or process could act as a barrier to exports to the adopting country, if local testing were required. Note that this is trade promotion in both directions, facilitating both exports from and imports into the country entering the MRA. International agreement on the form and content of MRAs is coordinated by the International Laboratory Accreditation Cooperation (ILAC).

The International Laboratory Accreditation Cooperation (ILAC)
"This developing system of international MRAs among accreditation bodies has enabled accredited laboratories to achieve a form of international recognition, and allowed data accompanying exported goods to be more readily accepted on overseas markets. This effectively reduces costs for both the manufacturer and the importer, as it reduces or eliminates the need for products to be retested in another country." (ILAC website).

ILAC have explored the scope for research based on members states' experience to assess the impacts of MRAs on trade, but found that the difficulties of methodology and availability of evidence prevented effective analysis. However there are some plans to re-visit the topic of impact in the near future. Such empirical evidence would be helpful in filling out the picture of the economic benefits arising from independent accreditation bodies and the framework of mutual recognition between them.

MRA- Japanese equipment

In an important paper in *Measure,* Usuda and Henson (2012) develop a method for assessing the benefits of equivalence of measurement standards between counties, based on the cost of non-equivalence, e.g. where products accepted as within tolerance by the exporter fall outside of tolerance under the measurement standards used by the importer, and, of course, vice versa. This is in the context of the International Committee for Weights and Measures' (CIPM) Mutual Recognition Arrangement framework for mutual acceptance of measurement standards. The economic values are estimated as the share of products that would be in the 'false positive' and 'false negative' zones were discordant measurement standards to be applied by seller and buyer.

The role of accreditation in this calculation lies in the degree of uncertainty of measurement of the product and the degree of variation in the measuring equipment used. Through accreditation of the testing facilities and of the calibration services, both of these sources of error are minimised.

UK exports

Interviews with representatives of businesses and trade associations provided examples of the benefits to production and trade of the application of international standards supported by the accreditation framework. In the case of international trade examples include:

- 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.

Detailed evidence on the scale of the trade effect was not, though, available. More generally, it is well established that product standards can be trade enhancing, through establishing confidence in product characteristics (Swann et al, 1996), and this effect can be supported by accredited conformity assessment. The evidence from NPL's survey of customer benefits

indicates that manufacturing and business services are amongst the most intensive uses of UKAS supported measurement services and these are also amongst the largest exporting sectors in the UK, implying the UKAS accreditation is a factor in promoting international competitiveness.

6.2 Environment and Health

Accreditation has an important role to play in areas where economic activity can have effects on the public or on the environment that are not priced in the decisions of buyers or seller - economic externalities. The need for frameworks of supervision or regulation to ensure public safety or to provide protection for environmental goods can be supported by accreditation of the bodies that undertake testing or inspection of potentially hazardous equipment or materials. A significant share of the UKAS accredited bodies is active in these areas. The assurance that businesses in the affected sectors have access to accredited services enables regulatory frameworks to rely more on specifying desired outcomes than on detailed specification of practices and costly supervision.

In the areas of provision of drinking water e.g. to new buildings, the regulation requires that testing of the supply is undertaken by a UKAS accredited lab, which relieves the regulator of the need to invest in its own testing facilities, thus saving public expenditure.

The accreditation framework has recently been extended to legionella risk assessments. These are a legal requirement for employers and other building owners and managers and accreditation offers the assurance that the assessment and the necessary testing is carried out by competent operators.

6.2.1 Asbestos

Although there has long been awareness of the dangers of certain forms of asbestos, it remains a potential threat to public health because of the very large amounts installed in older buildings, which may become a risk in the event of major changes such as demolition or refurbishment. A survey for the possible presence of asbestos and if apparently present, testing for the type and potential damage and identification of appropriate treatment is a regulatory requirement.[4] The survey and testing are carried out by suitably qualified and trained operative in survey companies and testing labs. Under the regulation, testing has to be undertaken by a UKAS accredited laboratory. Surveys are not so regulated and there are thought to be very many small asbestos surveying firms. Many, but by no means all, survey firms are accredited by UKAS. In sum, asbestos is one of the largest sections of UKAS coverage, with several hundred test labs and survey businesses accredited and the asbestos.

Because of the health risks, all building contractors, developers etc need to ensure that the presence of asbestos was investigated and samples tested. In the event of negligence or failure to comply with the requirements for health and safety, litigation of legal action would follow. The UKAS accreditation arrangement - ensuring that the most critical element in the asbestos review process - testing for harmful forms - is carried out by labs whose technical

[4] "The Control of Asbestos Regulations 2012 (CAR 2012) and more specifically Regulation 4: 'Duty to manage asbestos in non-domestic properties sets a legal requirement for owners and occupiers of non-domestic buildings to carry out a suitable assessment to determine whether asbestos is present or liable to be present.'" UKAS website.

competence and management processes, have been independently audited. And use of a UKAS accredited surveyor[5] also reduces the risk of such costs as well as the damage to public health that could result from poor practice. The economic value of assurance of competence in this case could include:

- Avoidance of costly litigation
- Better public health outcomes
- Lower costs of insurance against these risks (see below for an example).

It has not been possible to attempt to estimate the monetary equivalent value of these benefits within the scope and resources of this study. However, given the pervasiveness of the asbestos problem and the substantial size of the surveying and testing sector that address them, it is likely that these benefits are extremely high. An exercise to estimate monetary equivalent values would be possible, by researching the reduction in incidence of asbestos related diseases attributable to systematic surveying and testing. Economic values of the improved health outcomes could be estimated using methods widely adopted in health economics. An indicator of the multiplier or 'marginal effect' of UKAS accreditation on these estimated values would also be required. So, while feasible, such a study would probably be costly.

6.2.2 Environmental Management Systems: Defra Study

A recent evidence based study, sponsored by the Department for Food and Rural Affairs reviewed the impact of the adoption of Environmental Management System to Standard ISO14001 in a sample of 31 SMEs (Bennin, 2012). Findings of this study are not generalizable to a wider population. Major conclusions stated in this report are:

- *Commercial and marketing opportunities were the main trigger for the SMEs' decision to adopt an EMS.*
- *Just over a third of SMEs in the study achieved new sales as a result of their certified EMS, quoting an average value of £14,961 per £m turnover in the year following certification.*
- *It was reported that meeting regulations was the main drivers for maintaining the EMS certificate for medium size firms and those in manufacturing sectors, with market opportunities more important in services sectors and for small enterprises."*
- *Average cost savings over 2 years of £4,875 per £m turnover were reported, with costs of certifying and implementing the EMS calculated at £1,362 per £m turnover, a substantial return on the investment.*
- *28 SMEs made an average cumulative saving in carbon dioxide equivalent of 38.9 tonnes per £m turnover per SME and that the carbon savings improved over time, with year 2 figures up 59% on Year 1 figures. So adapting methods and practices under the guidance of the EMS generated significant social as well as private benefits.*

6.3 Health services

In the health services, UKAS has some application specific standards and an accreditation framework to support them, and two of these and the nature of the benefits from them are described below. More generally, as a very large purchaser and user of specialised medical

[5] Accreditation is a rigorous and on-going assessment to ISO/IEC 17020 of an asbestos surveying organisation.

equipment, the health service is a large market for quality infrastructure services such as calibration, inspection and testing. It is the impression of some experts in these services that the take up of accredited services, for example calibration, is relatively low, outside of the dedicated areas already noted. However this has not been systematically investigated as part of this study. Similarly to the case of the health effects of asbestos surveying and testing, it would be possible in principle, to design an evaluation of the impact of accreditation via other parts of the health service, but this would require the collection of considerable information on the take up of accreditation in these services and the performance of labs or departments with and without the use of accredited services..

6.3.1 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 though 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.

6.3.2 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, and 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 benefit of accredited status include:

- it reduces the need for inspections by regulatory agencies such as the Care Quality Commission.
- customer service is improved through eg 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.
- Accreditation 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 ISO15189, 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.

Accreditation 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. One example is 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.

6.4 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 3rd 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.

6.5 Forensics

UKAS has a role in the assessment of forensic science services. For example, a significant share of forensic testing is already undertaken by specialist testing labs, including LGC. Butt,

especially since the demise of the national forensic science service, UKAS has seen increasing demand for assessment of police force forensic services, who need to increase their capacity. Accreditation of services is a strong recommendation by the Association of Chief Police Officers. A case study from Lancashire police service *Accreditable in-sourcing* has been recently published in *Police Professional* August 30 2012.

Its main results are stated as follows.

> *Since out-sourcing has become the norm for police forensics services Lancashire have been able to bring the early stages of a forensics project in-house by gaining accreditation for their own teams. They can also be at crime scenes quickly. They have gained UKAS accreditation for search and recovery of body fluid and tissue samples. Testing can be undertaken more quickly than despatching to outside labs, speeding up investigation. All their footwear and drugs testing, and initial screening for other materials so that only those tested positive are sent to an external lab. Lancashire have recruited ex Forensic Science Service staff so increasing their skills and the range of tests that can be conducted in-house. It is estimated that savings of £500k pa from the in-house services. Lancashire's service is developing as a model and they have held open day to demonstrate their accredited processes to other forces. This cost saving cannot, though, be generalised to the circumstances of other police forces and used as an estimate of the financial benefit of accreditation. The internal savings in part represent displacement – a substitution of in-house for external services, which themselves would likely be accredited.*

6.6 Accreditation and intellectual property

In the framework of the UK innovation system, UKAS accreditation currently is mainly concerned with supporting and enhancing the reputation and efficacy of the quality infrastructure, which has been the focus of most of this study. Another crucial component of the broader infrastructure supporting innovation and economic performance is the system of intellectual property rights, mostly managed by the Intellectual Property Office (IPO). These rights include patents, registration of designs, copyright and trademarks. There has so far been little direct involvement of standardisation in the IP framework, and consequently little scope for UKAS accreditation to directly affect the operations and impact of IP.

However there is some evidence that standards, including Quality Management Standards such as ISO 9001, which does have accreditation support, are complementary to IP use in the innovation system.

An example can be found in the economic performance models set out in Annex C and summarised in Sub-section 5.3 above. These indicate (see Table C.2) that a mode of innovation that prioritises the use of IP has a positive correlation with the intensity of take up of accredited ISO 9001 management certification by businesses. The IP intensive technology mode exhibits strong correlation with performance indicators, suggesting that accredited quality management standards have an indirect effect on economic performance, confirming the result for business performance summarised above.

This statistical relationship between accredited generic management standards and IP intensive innovation perhaps indicates some scope for more IP management specific standards to be developed, a possibility corroborated by a perceived low adoption of IP by UK businesses. This low penetration is observed in business innovation surveys and in

surveys and inquiries by the IPO itself. Businesses especially SMEs have reported barriers to the use of IP arising from difficulties and costs of enforcement as well as lack of in-house expertise in IP management. These issues are partly addressed in the market place through a specialised sector of IP management advice services. To strengthen the promotion of IP use through this mechanism, as part of its efforts to reduce barriers to the take up of IP, the IPO has developed in conjunction with BSI a management (process) standard for these advisory services. (BS 8538). However the adoption rate of the standard has so far been limited. A possible reason for this low adoption rate is that the final customers do not perceive that self-certification of use of a standard by advisors is of material value to them. The importance of customer demand in stimulating the use of accredited services is documented by the UKAS/BMTA survey results. Developing accredited certification against BS 8638 may be one solution to provide greater assurance of compliance to the market and would be an interesting and potentially important extension of the tried and tested accreditation framework into new areas of the innovation system.

7 Conclusions

UKAS accreditation provides assurance of technical and managerial competence and reliability across diverse parts of the economy, in both the market and public service sectors. The direct total cost to users is low and this report has shown that the leverage is very large, through supporting the quality infrastructure that in turn enables higher quality, more innovative and safer economic activity. We have drawn upon a wide spectrum of evidence, including published literature and case studies, interviews with experts in businesses and associations, empirical and statistical data and a new survey of UKAS customers.

There are multiple routes to economic benefit and each can be shown to show a significant return on investment although not all can be directly quantified.

Commercial benefits to businesses, and to economic performance, arise through the promotion of innovation and productivity, and it has been possible to arrive at indicative quantification of this type of benefit, using information from surveys:

- In the market for the services covered by UKAS, the immediate value to users measured in willingness to pay and in service quality can be indicatively estimated at around £295m per annum.
- Downstream effects on growth and productivity, both through support for innovation enhancing knowledge flows and for technical and managerial efficiency have been shown to be significant in estimated models of economic performance.
- These can be indicatively quantified as a further value of approximately £320m per annum.

Therefore the measurable benefits of accreditation are estimated to be in the region of £600m per annum.

Additionally, the following channels of impact can be identified, although for reasons briefly outlined in the relevant sections, it has been beyond the resources of this study to undertake the research and evidence gathering that would enable quantification. It is though a plausible assumption that the totality of these benefits could be very substantial. But it is impossible to make even an educated guess at the order of magnitude.

- Public health and safety are advanced by accredited services in areas as diverse as diagnostic imaging, pathology labs, forensic testing and the management of the risks from asbestos in buildings.
- International trade is enabled through the assurance of quality and reliability while international mutual recognition of accredited testing and certification reduces potential barriers to trade.
- Efficiency in industry is promoted by accreditation support for the integrity of the National Measurement System, which inter alia leads to the avoidance of costs, for example of waste and re-working arising from non-conforming measurement.

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Appendix A UKAS/BMTA questionnaire

Background and purpose of the questionnaire

The UK Accreditation Service (UKAS) and the Department for Business, Innovation and Skills have commissioned a study to capture the value of accreditation in the economy. The study is being conducted by Dr Ray Lambert and Dr Marion Frenz of Birkbeck, University of London. The study covers all aspects of UKAS accreditation. To help with comprehensive and reliable evidence collection, we would be grateful if you could complete this simple questionnaire. If you have any questions about the survey, would like the opportunity to expand on your contribution, or to talk to the team in person, please contact Ray Lambert (r.lambert@bbk.ac.uk).

Any information provided will be presented in summarised and aggregated form only. Respondents and individual answers will not be identified, reported or shared. Aggregated results of this questionnaire will feed into a report on the Economics of Accreditation.

Questions

1. What are the main activities of the business? Tick all that apply.

Calibration	☐	Imaging services	☐
Testing	☐	Medical laboratories	☐
Certification	☐	Manufacturing	☐
Inspection	☐	Other (please specify)	

2. What is the size of your business measured in number of employees?

0-9 ☐ 10 to 49 ☐ 50-249 ☐ 250 or over ☐

3. How does accreditation fit with your business? Tick all that apply.

Accredited service supplier ☐
Accredited service user ☐

4. What is your estimated percentage share of accredited services out of total services? Provide estimated percentages using a scale from 0 to 100.

	Purchases %	Sales %
All services		
Calibration		
Testing		
Inspection		
Certification		
Imaging services		
Medical laboratories		
Other		

5. Do the following accredited services have a higher/lower price compared to none accredited services? Please use the following scale.

1= Over 10% higher
2= Up to 10% higher
3= No difference
4 = Up to10% lower

5 = Over 10% lower
9= Not applicable

Calibration	
Testing	
Inspection	
Certification	
Imaging services	
Testing	
Medical laboratories	
Others (please specify)	

*Please insert numbers from 1 to 5 or 9.

6. How important is accreditation to your business? Please tick one.

Not important ☐
Low importance ☐
Medium importance ☐
High importance ☐

7. What are the main benefits of accreditation to your business?

8. Can you quantify the economic value of accreditation to your business? If so, please provide a figure.

Appendix B Mixed modes of innovation

The methodology and results presented here are taken from an earlier report entitled Innovation Dynamics and the Role of the Infrastructure (Frenz and Lambert, 2011). This appendix summarises the underlying methodology and statistical results.

The report develops innovation modes through exploratory factor analyses of the innovation survey data, a methodology which we first adopted in an international context and work reported for the OECD (2009). Innovation modes are bundles of activities undertaken jointly by firms to bring about new developments in products and processes as well as in operating efficiency. 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.

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). 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, such as the use of standards as a source of information for innovation also feed directly into the innovation modes. 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 firm was high or low on an innovation mode.

Variables feeding into the factor analysis are taken from 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.

The variable that is of central importance to this report is the use of standards, and, linked with this, the effects of accreditation, with metrology. The innovation surveys include information on the use of industry, technical or service standards[6] as information for innovation. Table B1 provides an overview of the variables feeding into the innovation modes.

[6] We refer to formal standards and codified knowledge (and not to de facto market standards that are selected by users).

Table B.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
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

Factor analysis is applied to these variables 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.

The individual variables, listed in Table B.1, and taken from the UKIS2009, are on the left hand side of Table B.2. They determine the rows of the table. Across the top are the 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 B.2 Mixed modes of innovation. Reference period is the three-year period 2006 to 2008. Dataset is the UKIS2009

Modes / Variables	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
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. 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 in our later analyses. 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. 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.

Appendix C Innovation modes, measurement knowledge and quality management certificates

This appendix contains empirical results linking to innovation modes the use of measurement knowledge across specific industries and the uptake of quality management certificates within the geographical environment. The innovation modes are introduced in the text and in-depth in Appendix A.

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 knowledge. There are 97 industry groups identified in the variable. The variable is directly taken from the work done by Paul 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 2003 and 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 further 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 innovation survey via the locational information. There are 55 geographical regions identified by the variable. These data are from the QA Register, which is the only available database that lists 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).

The innovation modes are linked with two exogenous variables that capture different dimensions of the quality infrastructure. Firstly, 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. We further break down this variable into its individual components (a) the stock of standards in an industry and (b) the purchases of instruments in an industry. Secondly, we use the stock of accredited certificates of conformity with the management standard ISO 9001.

Table C.1 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 (values o to 6)
2	Stock of standards	Quartiles of the stock of standards of the enterprise's industry (values 0 to 3)
3	Instrument purchases	Quartiles across instrument purchases of the enterprise's industry (values 0 to 3)
4	ISO 9001	Number of ISO 9001 certificates within the geographical area of an enterprise

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 quartiles 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.

Table C.2 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
Combined score[a]	-0.01	0.02	0.01
	(0.00)*	(0.01)**	(0.01)+
ISO 9001[b]	0.00	0.01	0.01
	(0.00)+	(0.00)*	(0.00)**
Design consultancy	-0.02	-0.02	-0.01
	(0.01)*	(0.02)	(0.02)
Human capital	0.01	0.06	0.05
	(0.00)**	(0.00)**	(0.00)**
International markets	0.05	0.13	0.07
	(0.01)**	(0.01)**	(0.01)**
Industry dummies	Included	Included	Included
Constant	-0.06	0.17	-0.00
	(0.03)*	(0.07)**	(0.05)
Observations	6,232	6,232	6,232
R-squared	0.07	0.12	0.09
F-statistic	17.05	40.53	26.70

	Wider innovating	Market-led innovating	External process
Combined score[a]	0.00	0.02	0.01
	(0.01)	(0.00)**	(0.00)*
ISO 9001[b]	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Design consultancy	0.01	-0.05	-0.02
	(0.02)	(0.01)**	(0.02)
Human capital	0.03	0.02	0.01
	(0.00)**	(0.00)**	(0.00)**
International markets	0.05	0.05	0.01
	(0.01)**	(0.01)**	(0.01)
Industry dummies	Included	Included	Included
Constant	-0.04	-0.05	0.10
	(0.05)	(0.04)	(0.05)*
Observations	6,232	6,232	6,232
R-squared	0.04	0.06	0.02

F-statistic	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 2005
[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. ISO 9001 is associated with investing in intangibles and using codified knowledge. The next table divides the variables combined score into: (a) the stock of standards in an industry and (b) the purchases of instruments in that industry.

Table C.3 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
Stock of standards	-0.01	0.02+	0.01
	(0.01)	(0.01)	(0.01)
Purchases of instruments	-0.01	0.02*	0.01
	(0.01)	(0.01)	(0.01)
Human capital	0.01**	0.06**	0.05**
	(0.00)	(0.00)	(0.00)
International markets	0.05**	0.12**	0.07**
	(0.01)	(0.01)	(0.01)
Industry dummies	Included	Included	Included
Constant	-0.07**	0.18**	0.01
	(0.03)	(0.06)	(0.05)
Observations	6,567	6,567	6,567
R-squared	0.07	0.12	0.08
F-statistic	18.47	43.57	27.86

	Wider innovating	Market-led innovating	External process
Stock of standards	0.01	0.02**	0.01
	(0.01)	(0.01)	(0.01)
Purchases of instruments	0.01	0.02**	0.01
	(0.01)	(0.01)	(0.01)
Human capital	0.03**	0.02**	0.01**
	(0.00)	(0.00)	(0.00)
International markets	0.04**	0.05**	0.00
	(0.01)	(0.01)	(0.01)
Industry dummies	Included	Included	Included
Constant	-0.02	-0.09*	0.08+
	(0.04)	(0.03)	(0.04)
Observations	6,567	6,567	6,567
R-squared	0.04	0.05	0.01

F-statistic	11.33	16.06	4.38

Source: IS2009. Estimation method is OLS. We report robust standard errors in parentheses.
** p<0.01, * p<0.05, + p<0.1

The stock of standards and instrument purchases in an industry are correlated with investing in intangibles and market-led innovating with a similar strength and coefficient size.

Appendix D Impact on performance

Enterprise-level innovation modes and the industry and geographical variables on measurement knowledge and QMS certifications are used as independent variables in regressions that predict labour productivity (turnover per employee) and changes in productivity (while controlling for productivity levels in the pervious periods as well as a set of control variables). The variables that we use to measure performance are taken from the innovation surveys. They are summarised in Table D.1.

Table D.1 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

The key independent variables used in the regressions are measures of the innovation modes, measurement knowledge and QMS accredited certification. We also include a set of customary control variables.

Table D.2 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

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 regression results were first reported in Frenz and Lambert (2011).

Table D.3 Measurement knowledge, QMS certification and productivity in 2008

	Productivity	Change in productivity
Combined Score	0.10	0.04
	(0.02)**	(0.01)**
ISO 9001	0.01	0.02
	(0.01)	(0.01)*
Using codified knowledge	0.13	0.06
	(0.05)**	(0.03)*
IP/techn. innovating	0.21	0.04
	(0.06)**	(0.04)
Investing in intangibles	-0.04	-0.01
	(0.04)	(0.03)
Wider innovating	0.01	0.04
	(0.05)	(0.03)
Market-led innovating	-0.03	-0.00
	(0.04)	(0.03)
External process modernizing	0.08	0.06
	(0.06)	(0.04)
Design consultancy	-0.04	-0.01
	(0.04)	(0.02)
Human capital	0.13	0.05
	(0.01)**	(0.01)**
International market	0.43	0.17
	(0.04)**	(0.04)**
Log employment	0.96	
	(0.01)**	
Change in employment		0.45
		(0.05)**
Productivity in t-1		-0.37
		(0.04)**
Industry dummies	Included	Included
Constant	4.61	1.81
	(0.25)**	(0.21)**
Observations	2,687	2,561
R-squared	0.80	0.29
F-statistic	271.58	6.27

Source: IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses. The coefficients on the key independent variables relate to percentage changes in turnover per employee in 2008. The reference period for the innovation modes is 2002 to 2004 and for combined score 2003.
** p<0.01, * p<0.05, + p<0.1

The industry and geographical level variables, combined score and ISO 9001 are positively correlated with productivity, providing some support for the economic importance of such activities. Using codified knowledge, such as standards, and IP technology innovating are the two modes that show the strongest associations with productivity. In the following two tables the combined score variable is disaggregated into its components, the stock of standards relevant to a group of sectors and those sectors purchases of instruments.

Table D.4 Measurement knowledge, QMS certification and change in turnover and employment in 2008.

	Change in turnover	Change in employment
Combined Score	0.00	0.01
	(0.01)	(0.01)
ISO 9001	0.03	0.01
	(0.01)*	(0.01)+
Using codified knowledge	0.07	0.01
	(0.04)+	(0.03)
IP/techn. innovating	0.07	0.05
	(0.04)+	(0.03)
Investing in intangibles	0.02	-0.01
	(0.03)	(0.02)
Wider innovating	0.12	0.06
	(0.04)**	(0.03)*
Market-led innovating	0.01	-0.00
	(0.03)	(0.03)
External process modernizing	0.04	0.03
	(0.04)	(0.03)
Design consultancy	-0.01	0.02
	(0.02)	(0.02)
Human capital	0.03	0.02
	(0.01)*	(0.01)*
International market	0.07	0.01
	(0.03)*	(0.02)
Turnover in t-1	-0.10	
	(0.02)**	
Employment in t-1		-0.05
		(0.01)**
Industry dummies	Included	Included
Constant	1.04	-0.08
	(0.19)**	(0.13)
Observations	2,570	2,569
R-squared	0.07	0.03
F-statistic	2.95	2.16

Source: IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses. The coefficients on the key independent variables relate to percentage changes in turnover per employee in 2008. The reference period for the innovation modes is 2002 to 2004 and for combined score 2003.
** p<0.01, * p<0.05, + p<0.1

Table D.5 Measurement knowledge, QMS certification and productivity in 2008

	Productivity	Change in productivity
Stock of standards	0.17**	0.07*
	(0.03)	(0.03)
Instrument purchases	0.05*	0.03
	(0.02)	(0.02)
Using codified knowledge	0.11*	0.05+
	(0.04)	(0.03)
IP/techn. innovating	0.18**	0.03
	(0.06)	(0.04)
Investing in intangibles	-0.02	-0.01
	(0.04)	(0.03)
Wider innovating	0.01	0.04
	(0.05)	(0.03)
Market-led innovating	-0.02	0.01
	(0.04)	(0.03)
External process modernizing	0.08	0.05
	(0.05)	(0.04)
Human capital	0.12**	0.04**
	(0.01)	(0.01)
International market	0.42**	0.14**
	(0.04)	(0.03)
Log employment	0.97**	
	(0.01)	
Change in employment		0.44**
		(0.05)
Productivity in t-1		-0.35**
		(0.04)
Industry dummies	Included	Included
Constant	4.54**	1.76**
	(0.25)	(0.20)
Observations	2,853	2,721
R-squared	0.79	0.27
F-statistic	290.8	6.473

Source: IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses. The coefficients on the key independent variables relate to percentage changes in turnover per employee in 2008. The reference period for the innovation modes is 2002 to 2004 and for combined score 2003.
** $p<0.01$, * $p<0.05$, + $p<0.1$

Table D.6 Measurement knowledge, QMS certification and change in turnover and employment in 2008.

	Change in turnover	Change in employment
Stock of standards	-0.01	0.00
	(0.03)	(0.02)
Instrument purchases	0.02	0.02
	(0.02)	(0.01)
Using codified knowledge	0.06	0.01
	(0.03)	(0.03)
IP/techn. innovating	0.06	0.05
	(0.04)	(0.03)
Investing in intangibles	0.01	-0.02
	(0.03)	(0.02)
Wider innovating	0.12**	0.06*
	(0.04)	(0.03)
Market-led innovating	0.02	0.00
	(0.03)	(0.02)
External process modernizing	0.03	0.03
	(0.04)	(0.03)
Human capital	0.02+	0.02*
	(0.01)	(0.01)
International market	0.05	0.00
	(0.03)	(0.02)
Turnover in t-1	-0.10**	
	(0.02)	
Employment in t-1		-0.04**
		(0.01)
Industry dummies	Included	Included
Constant	1.03**	-0.06
	(0.18)	(0.12)
Observations	2,730	2,729
R-squared	0.07	0.03
F-statistic	3.067	2.208

Source: IS2005, 2007 and 2009. Estimation method is OLS. We report robust standard errors in parentheses. The coefficients on the key independent variables relate to percentage changes in turnover per employee in 2008. The reference period for the innovation modes is 2002 to 2004 and for combined score 2003.
** p<0.01, * p<0.05, + p<0.1

Appendix E Accreditation Standards

European and International Standards
ISO/IEC 17011:2004 Conformity assessment – General requirements for accreditation bodies accrediting conformity assessment bodies
ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories
ISO 15189:2007 Medical Laboratories - Particular requirements for quality and competence
ISO/IEC 17020:1998 General criteria for the operation of various types of bodies performing inspection
ISO/IEC Guide 65:1996 (EN 45011:1998) General requirements for bodies operating product certification systems
ISO 14065:2007 Greenhouse gases: requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition
ISO/IEC 17024:2003 General requirements for bodies operating certification of persons
ISO/IEC Guide 43 - Part 1:1997 Development and operation of laboratory proficiency testing
ISO/IEC 17021:2006 Conformity assessment: requirements for bodies providing audit and certification of management systems
ISO Guide 34:2000 General requirements for competence of reference material producers

Source: UKAS