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Institutions and Long-Run Growth in the UK:
the Role of Standards[1]

By Paul Temple[¶], Robert Witt[¶], and Chris Spencer[¶]

Abstract

In this paper we consider the relationship between the standards created by national standards bodies and long run economic growth, exploring the relationship in the context of the UK and the British Standards Institution (BSI). We suggest that standards provide a key enabling mechanism for the widespread diffusion of major technologies, while being generally supportive of incremental innovation and general technological understanding. In order to further understanding of this mechanism we measure the 'output' of the BSI by estimating the size of the BSI 'catalogue' available to the economy since its inception in 1901. The measure allows us to estimate an augmented production function for the UK economy over the period 1948-2002. Within a co-integrating framework, we find a statistically significant and unique co-integrating vector between labour productivity, the capital-labour ratio, exogenous technological progress and the BSI catalogue. The long-run elasticity of labour productivity with respect to the standards stock is estimated to be about 0.05, so that the rapid growth of the catalogue in the post-war period is associated with about 13% of the aggregate growth in labour productivity.

Key-words: standards, technological change, productivity.
JEL codes: O11, O33, O47, L52, C22

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Introduction

It is unarguable that individual standards – documents which provide technical specifications – can improve productivity. The first 'public' standard in Britain in 1901 reduced the number of types of steel sections from 175 to 113 and the number of tramway gauges from 75 to 5. Estimated cost savings to the steel industry amounted to £1 million a year[2]. But do the institutions which produce them have measurable impacts at the level of the whole economy? Below we tackle this question in the context of the British Standards Institution (BSI), arguing first that standards provide a key enabling device for the uptake (diffusion) of technology. Their input needs to be seen as complementary to other inputs into the process of technological change, most importantly acting to ameliorate possible market failures in the diffusion process. We then suggest that the 'catalogue' of standards provides a plausible indicator of the productivity enhancing benefits of the institution. Finally, an econometric model is used to show that there is a measurable and validated statistical association between the catalogue and productivity growth in the UK, at least in the period since World War II.

The plan is as follows. The next section considers the general relationship between public standards and economic growth, seeing the main contribution via the impact upon processes of technological diffusion. Section three then considers a measure of the 'output' of the BSI, seeing it in terms of the growth and maintenance of its 'catalogue'. This measure is then used to estimate a simple augmented production function model of labour productivity growth in the UK over the period 1948-2002. To anticipate our results, we find that that the growth of the catalogue is associated with around 13% of productivity growth. The concluding section interprets our results.

Standards, Technological Change and Productivity Growth.

Both the theory and the empirical analysis of economic growth have come a long way in the last two decades. Broad agreement on the significance of the role played by technological progress in achieving growth has meant that much attention has focused on the stimuli provided by markets and institutions in creating such change. Here however, the well-known Schumpeterian distinction between 'innovation' and 'diffusion' as conceptually distinct elements in technological change, suggests an interesting point of difference, with an emphasis in modern (endogenous) growth theory on the part played by innovation. This is not perhaps surprising. It is commonly suspected that – unaided – firms will under-provide resources for innovation. It not only involves fixed costs, but is also risky, not least because a competitor may be in a position to reap the benefits. In situations of fixed costs, model builders have been keen to demonstrate the importance of the size of the market, while noting the potentially deleterious effects of competition. The recommended institutional support in such circumstances involves the creation of intellectual property rights, or the public support of research activities whether through direct provision for research or through R&D subsidies. By contrast, most endogenous growth theory has tended to downplay the significance of diffusion processes, with innovations being adopted at once.

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[2] History of the BSI Group (BSI undated)

Empirical analysis, while hardly denying the role played by innovation has also highlighted important differences between firms and economies in their *access* to, or uptake of, technology. At the same time a large body of theory has shown that markets may also fail in delivering efficient diffusion paths. Stoneman and Diederen provide a convenient summary of such failures, noting the role of imperfect information, market structure, and externalities (Stoneman and Diederen 1994). In economic policy moreover, an increasing interest in the diffusion of technology has been apparent for some time, not least in the UK.

How do standards fit into the Schumpeterian trilogy? In order to avoid contextual dependence, we define standards here as consisting of documents providing "technical specifications that may be adhered to by a producer, either tacitly or as a result of a formal agreement (David 1995)". More particularly we shall be referring, unless stated otherwise, to the sub-set of these documents which are the measurable output of National Standards Bodies (NSBs). In the case of the UK this body is the British Standards Institution (BSI). The documents themselves are the outcome of a co-operative process among the participants of technical committees. Ideally the outcome should represent the interests of various 'stakeholders', communities of producers and users.

The potential benefits arising from individual standards are reasonably well known. Four main economic functions are usually identified[3]:

- Providing for *inter-operability* or compatibility between different parts of a product or more generally between different elements in a system or network.
- The provision of a *minimum level of quality*, which may be defined in terms of functionality or safety of products.
- The *reduction of variety*, allowing for economies of scale.
- The provision of *information* .

NSBs are not the sole source of such technical documents. Market processes do of course create standards of a similar nature (often described as 'de-facto' or 'proprietary' standards), where individual firms can and do develop their own standards to improve their own profitability, while consortia also develop standards for perceived mutual economic gain. The important point however is that the creation of standards is itself subject to market failure, and there is a strong presumption that, unaided, markets will under-provide for standards. This last point is probably well understood: the development of standards involves fixed costs, and the gains may not always be appropriable by the individual firm which develops one[4]. Together, these give standards properties akin to a 'public good'. Moreover, as Swann (2000) observes, these standards do not always possess two qualities of the institutionally produced standard:

- The first is *'openness'.* This means that it is available – on an equal basis – for all competitors. Some proprietary standards may be open – but there is no presumption of this – indeed probably the opposite. This characteristic may be particularly important for small firms. Proprietary standards tend to create market power, and higher prices may slow down the rate at which firms adopt an innovation. Inter-

[3] For a general survey of the economics of standardization, see Swann (2000)
[4] They may however be sufficiently appropriable to make standards 'contests' or 'races' an interesting phenomenon in their own right

temporal price discrimination may enhance this effect (Stoneman and Diederen, 1994).

- The second characteristic of 'public' standards is that of *'credibility'*. Government sponsorship and other aspects of standards help to create confidence that a standard may achieve widespread use.

One other possible differentiating characteristic of the standard is that, being the outcome of the deliberations of a committee, and based upon the need to be based upon consensus, they may take longer to produce than market-led standards. This has been a frequent criticism of standards setting institutions, particularly in sectors where technological advance is rapid.

Arguably, each of the above functions and characteristics can be viewed as 'enabling' the spread of technology. In recent years economic theory has focused primarily on the first kind of function reckoned to be vital for the widespread adoption of 'system technologies' in (for example) computing or in communication technologies. Here the benefits from adoption and the extent of diffusion depend upon the number of existing users either directly with the development of a network – of mobile telephones for example, or indirectly via 'hardware-software' effects in which the widespread adoption of a technology depends upon the existence of complementary products. In such examples, referred to as cases of *network externalities,* standards are clearly integral to adoption. In many cases it is the agreement and co-ordination that a standard achieves that is important – the precise characteristics of the standard – and whether it is actually the 'best' standard, are far less important[5].

It is well recognised in the literature that network externalities may be particularly important in the spread of several key technologies in the past century or so, especially so-called 'general purpose engines' as noted for example by David (1990). This term refers to significant innovations which serve as common modular units with a wide variety of applications using appropriate engineering designs. Familiar examples include Watt's steam engine (e.g. Crafts 2004), the dynamo (David 1990), or the computer as a component of information technology (Oliner and Sichel, 2000). In the development and diffusion of such major technologies, it is well known that 'standards' provide an essential input, establishing compatibility and interoperability between components in the system.

On occasion, historians have pointed to a lack of standardization as a stumbling block to the diffusion of a key technology. In the UK, the early history of electrification was notorious for the variety of standards in operation. Landes for example reports that "voltage varied from town to town or even from street to street; those systems that offered alternating current did so at different cycles; the effect on the electrical goods industry may easily be imagined" (Landes 1972, p. 434-5). It was only with the establishment of the Central Electricity Board, that the dominant pressure of 230v became something of a norm in the industry. In any event, Germany was well ahead in the diffusion of electric power in the inter-war period, and here a diversity of standards does not appear to have been a problem (ibid, p. 436).

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5 There are case studies beginning perhaps with David (1985) who used the example of the QWERTY design of keyboards, which suggest that the final standard selected is not always the 'best' from a technological standpoint. Because of the counter-factual nature of the exercise, it is very hard to substantiate. Although the accepted wisdom suggests that QWERTY is not as efficient a layout as others (notably the Dvorzak simplified), this conclusion is not universally accepted (see for example Liebwitz and Margolis, 1994)

The diffusion enabling and productivity enhancing benefits of standards are not by any means restricted to major technologies. Some economists have argued that these hardware-software effects may be considerably more widespread than these familiar examples, especially in relation to the way that labour force skills may be harnessed.

Moreover, while *compatibility* standards have attracted much attention in business and amongst policy makers, as well as economists, the other functions of standards can also be seen as impacting upon technology adoption.

Insofar as they provide *information*, standards promote technological understanding. As a recent study of standards points out, "Researchers, developers, construction engineers and marketing experts utilize … standardization documents as important sources of information about the state of the art in technology" (Blind 2004). As evidence in the UK, there is the fact that standards feature prominently as a source of information for innovators in the UK's Community Innovation Survey (CIS3)[6].

Many economic explanations of diffusion processes stress the role played by information in the uptake of a new technology. For example, the well-known epidemic model is based upon the idea that information passes on a 'word of mouth' basis amongst a homogeneous intermingling community. This model generates the familiar 'S-shaped' diffusion pattern [7] typically, but not universally, found in empirical studies[8]. In various respects however, the model is not entirely satisfactory[9] and more sophisticated models have begun to examine the nature and the quality of the information involved. A useful distinction is sometimes made between 'word of mouth' and common or 'broadcast' sources of information[10]. The initial broadcast may for example come from the manufacturers of the capital equipment or 'hardware' associated with the technology. In the CIS survey cited above for example, the response to the question of which sources of information are important, "suppliers of equipment, materials, components or software" features as a leading source for innovators and non-innovators alike. Allowing for some random process[11] there will be early adopters as a result of this common source of information. Arguably however the epidemic effect requires a different quality of information, one imbued with knowledge that comes from actual use of the technology[12]. Clearly such knowledge is more 'tacit' in character and may require 'word of mouth' transmission. This type of approach may for example help explain the importance of geographical agglomeration effects in industries where technological change is rapid. Arguably, the process of setting standards typically also adds economically valuable *user* information. Depending upon the context, we may wish to think of the publication of a standard as creating a more 'credible' broadcast effect, or substantially increasing the rate of interaction among the potential adopter population. The potential impact of a standard is even greater when, at the early stages of an innovation, there are several competing technologies, and standard setting resolves initial uncertainties. Clearly this

[6] And to a lesser extent amongst non-innovators. The survey shows that while information from other firms is particularly important, standards are roughly as important as a source of information as the trade press, and rather more important than consulting firms or universities.

[7] In which there is a relatively rapid period of growth some time after the initial innovation, which then slows at some particular date.

[8] For a recent review of such models see Geroski (2000)

[9] Geroski (2000) points to the fact that the we need an initial base of users before the process can begin, as well as the fact that the diffsuion path is not usually as symmetrical as the simple theory predicts.

[10] The broadcast form of information communication does not in general create an S-shaped diffusion path

[11] In a simple 'broadcast' model, some given % of the potential population adopt in any time period.

[12] Moreover, and for obvious reasons, the early broadcast information may not be entirely credible.

effect is amplified the presence of network externalities, and a series case studies document the impact of a standard in such competitive situations[13].

The other important model of diffusion processes in the literature is that based upon a heterogeneous target population – the 'probit' model which builds upon differing firm or consumer characteristics such as firm size or age. It is more popular with some economists because it is based upon individual profit maximising decisions, and does not rely on the imperfect spread of information. The diffusion process is then driven by some 'forcing' variable, such as rising real wages, or gradual improvements in the technology which reduce the price, which impact upon the decision to adopt. Standards setting can play a part in such models. Firm size is clearly relevant in that larger firms tend to have alternative strategies for overcoming the problems of the market where standards may be helpful, and which are not always available to smaller producers[14]. In such cases standards may induce smaller companies to adopt. The degree of risk aversion is another possibly relevant characteristic, where the credibility attached to a public standard affects the 'equilibrium' level of adoption.

Perhaps one more point needs to be made in relation to the probit model, namely that the distinction between diffusion and innovation becomes more blurred than in simple information models. One way of thinking about firm heterogeneity is in terms of the basic innovation being adapted and extended across a sequence of applications or markets through a process of incremental innovation according to user requirements. Swann (2000) evidently has this in mind when he develops models of product development with and without the direction given by formal standards acting as 'focusing devices'. While recognising that, in some sense, standards must constrain innovation at the outset, he argues that, when considered as a *sequential* process, the end result of the ordered process is one of 'thicker' markets, more competition, and less duplication of research effort, which is allowed to specialise instead on customer needs. His model also considers the impact of intellectual property rights in such a process. These may take the form of patent protection *or* proprietary standards both of which hinder the opening up of the product variety space.

In the case of the minimum quality function of standards, there may well be demonstrable gains in situations of information asymmetry, where buyers are unable to distinguish between 'high' and low qualities – at least in advance of purchase. If – as is likely - high quality producers face higher costs than low quality producers, they might find it hard to survive in such market conditions, giving us as case of 'Gresham's Law' in which the 'bad drives out the good'. Although there may be other ways in which producers can prevent its operation, minimum quality standards may be an effective means of mitigating the operation of the Law.

In summary, we argue that public standards provide - under a variety of circumstances - a vital input into the diffusion processes that underpin technological change. This input should not be seen as acting independently of other – perhaps 'deeper' -influences on technological change. The list here includes not just innovation in particular, but also the contribution of human and physical capital accumulation as well as economies of scale[15].

13 For citations see Swann (2000)

14 For example, the fixed costs that might attach to developing a reputation in some markets, or in developing a proprietary standard.

15 For example, it is commonly believed and entirely plausible that technological change has consistently been biased toward the employment of skilled labour. As far as such a concept is measurable the strong growth in human capital formation in most of the major economies has meant that the 'premium' on skills has not risen steadily in the long run. Although there is evidence of a rise in the last two decades, this does not seem to be the long-run picture; see for example Wood (1998) and evidence therein. A number of

Before moving on to the econometric analysis, a brief discussion of other relevant empirical literature may be useful.

Much empirical investigation in the economic growth literature has focused upon cross sectional or panel studies across many countries.[16] Perforce, these have been unable to shed much light on the role of individual national institutions. In a recent review of the evidence, Temple (1999) remarks that "despite the popularity of this endeavour, many believe that it is fruitless, partly because there are not likely to be any general answers. The appropriate research questions and answers will depend upon a country's particular situation, for instance whether a country is a technological leader or a developing country trying to catch up." (p. 119). Standards institutions are a good example of this proposition even within the group of "technological leaders", since the development of these institutions may vary considerably from country to country. In the US for example, the standards infrastructure is quite different from that of the UK, more sector specific and pluralistic in nature, and it would accordingly be very difficult to conceive of a measure that would capture the relative strength of standards setting institutions between these two countries[17]. There is therefore a genuine need for research on growth at the national level, if the institutional inputs into these processes are to be better understood.

There is however at least one substantial body of research that does develop in more detail the institutional structures that have a national and possibly idiosyncratic character. We speak here of a large number of contributions to the study of *national innovation systems*. While the term 'innovation' appears, it seems clear that this approach to technological change has a very broad understanding of the term, encompassing "the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, whether or not they are new to the universe, or even to the nation" (Nelson 1992). Amongst those contributing in this field, there is broad agreement that both *firm specific* investments, and the *national institutions* which support those investments, are strong drivers of technological change at the level of the national economy[18]. In this regard, the focus of many of these studies was on the role of particular government policies, and that played by educational systems and especially universities and the science base, in what may be highly distinctive national contexts. The important point underpinning these studies however was that distinctive national institutions can and, in practice do, help to sustain patterns of national technological capability, through

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authors have examined the importance of skill-biased technological change in recent years in increasing the relative demand for skills. However the precise source of this *acceleration* in the demand for skills is a matter of dispute. Wood argues that the cause of the acceleration – as opposed to the long-run trend - may be attributed to increased trade in manufactured goods between the advanced economies and the rest of the world, and the resultant increased (and in his explanation complete) specialisation of the advanced economies in skill-intensive sectors. The availability of skilled labour is of course one factor explaining the supply of standards, since it provides almost certainly the major input into the work of the technical committees, impacting upon whether the prospective net benefits in developing a standard are positive. As far as economies of scale are concerned, again it is arguable that while the potential for economies of scale exists independently of institutional and other contexts, their realisation does not. In his study of economies of scale and scope for example, Chandler (1990) documents the simultaneous need for investments in organizational skills if economies of either scale or scope can be realised. Public standards provide another such mechanism.

[16] i.e. those contained in the famous Summers-Heston dataset also known as the Penn World Tables. These data are obtained from benchmark studies of Purchasing Power Parities from the International Comparisons Programme (ICP) of the United Nations and national accounts data. For a description see Heston and Summers (1996).

[17] This is less obvious when the BSI catalogue is compared to say DIN in Germany or AFNOR in France, bodies which serve similar needs at the national level as BSI, both scope of their activities and the type of documents produced does differ from country to country.

[18] Important evidence for this resides in the relevance of innovation and technology in explaining specilialization in international trade, evidence that begins with Macdougall (1951) in a simple test of the Ricardian model of trade. More recenet evidence and a review see Wakelin

firm specific investments which have as a result a 'national flavour'. A central conclusion of this line of enquiry was that much technological knowledge is not 'codified' in the form of readily available information, but operates instead at the level of the firm, and the skilled individuals within it. Accordingly the major share of innovative effort is in the form of firm specific investments, particularly in more mature technologies. Nelson argues the reasons as stemming from the fact that knowledge about which types of incremental innovation is likely to yield a return, resides decisively with the *users* of the technology, who understand its strengths and limitations. Further, successful innovative strategies, frequently require the complex co-ordination of R&D, design, production, and marketing, which "tends to proceed much more effectively within an organization that itself does all of these" (Nelson, *op cit*, p. 278).

As yet, there is little hard evidence as to the relationship between aggregate 'public standards' and overall productivity growth. There is however a body of case study evidence which points to the importance of individual standards. The benefits from individual measurement and reference standards have for example been investigated by the US National Institute of Science and Technology, which reports social rates of return of the order of 63-423% (Tassey, 1995). Swann (2000) lists other cases, of relevance, particularly from the practitioner literature. The latter tends (naturally enough) to focus on individual company performance, rather than the overall social benefits from standardization, which may of course be very different. However, the well-known problem with case-study evidence is one of sample selection bias, and to aggregate on the basis of it could be highly misleading.

At the level of the whole economy, the only explicit attempt to measure the impact of standards for growth was carried out for Germany by Jungmittag et al (1999), who suggested that standards were responsible for a significant proportion of the growth in output of the German business sector between 1960 and 1996. For example, in the period from 1960 to 1990 (i.e. prior to re-unification), the authors report that standards contributed an estimated 0.9 percentage points to an overall growth rate of output of 3.3% per annum. This was reckoned to be second in importance only to capital accumulation over the whole period – and more important than other sources of technological change such as domestic innovation and the direct payment for imports of technology from abroad. Other studies have examined the impact of standards on trade performance (e.g. Swann et al 1996, Blind 2001). These have shown that at a sectoral level, standards have positive measurable impacts on intra-industry trade, stimulating both exports and imports. These impacts were moreover additional to those impacts stemming from changes in productivity, since both studies used price competitiveness as variables in the estimating equations, in addition to the measures of standards adopted. These studies have utilised measures of the *size* of the relevant standards stock as explanatory variables. We now consider this measure in the current context in more detail.

A Measure of the Contribution of Standards to Productivity: the BSI 'Catalogue'

Before moving on to an empirical model of the relationship between standards and productivity, we first consider the proposed measure of standards output. Here, following the studies described above (Swann et al 1996, Jungmittag et al 1999), we use the number of standards in the 'catalogue' available to producers as providing a convenient starting point.

At any one time, the catalogue – call this the *SCI* - is made up of the cumulated *publications* of standards up to that time less those that have been *retired or withdrawn*, i.e.

$$SCI(t) \equiv \sum_{i=t-\infty}^{i=t} P(i) - \sum_{i=t-\infty}^{i=t} W(i) \qquad (1)$$

where SCI is the measure of the standards catalogue at end of period t, P(i) is the number of standards published during any year i , and W(i) is the number of standards withdrawn (or retired) during any year i. SCI(t) is therefore a measure of the 'stock' of standards current at the end of t periods and which we argue serves as a proxy for the 'flow' of benefits to the economy during any interval of time t.

Ideally perhaps, we would wish to supplement this measure with several aspects of the 'condition' or 'quality' of the catalogue, and in particular a count of the number of standards by economic function. However this was not practicable given the information available to us, and in any event is complicated by the fact that many standards have more than one function, while all have some information content.

In order to justify our approach, it is helpful to think not so much of individual standards but in terms of the publications of a particular year, i.e. a particular 'vintage'. While the standards published within any vintage may be expected to create a positive net benefit to the economy, over time these benefits will decline, as the technology in which the standard is embedded becomes less relevant, the physical equipment to which it refers becomes obsolete, and so on. As a result the standards of a particular year (vintage), are withdrawn from the catalogue. A few are declared obsolete, but the large majority are 'replaced' or 'superseded' by a newer standard, better fitted to the current technological and business situation. Arguably therefore, the declining efficiency of any vintage is fully reflected in its declining share of the overall catalogue[19].

We can now illustrate the basic measure using our data on BSI standards. These were constructed from two data sources. First the BSI 'History Book' allowed us to count all BSI publications from the initial 'public' standard in 1901[20]. This source was discontinued as computerised records were introduced in 1985. Accordingly, from that date we use the PERINORM©[21] database. While this allows for a complete count of withdrawals, and

[19] An alternative would be to impose or estimate an age-efficiency profile for any particular vintage. This approach is for example used in the conventional method of estimating the gross capital stock, where it is assumed that the productivity of an asset is constant until the estimated scrapping date, the latter being based upon assumptions regarding the lives of particular assets, which may follow a statistical distribution. Arguably the present approach is rather better, in that we possess a detailed knowledge of retirements.

[20] Kindly made available to us by Mary Yates of the BSI Library

[21] A consortium of BSI, DIN, and AFNOR.

hence an accurate measure of the size of the catalogue (SCI) at any time t, we were unable to count all withdrawals using the History Book. Some estimates of withdrawals therefore had to be made for the period prior to 1985. Details of the methods adopted can be found in the Data Appendix to this paper. However, given our arguments above, the withdrawal of standards reflects the 'age-efficiency profile, of a particular vintage. The implied profile is shown in Figure 1a with the current state of the catalogue in terms of vintages in Figure 1b. On the basis of this, about 50% of the efficiency enhancing impact has taken place after six years.

Figure 2 shows how publications have grown since the initial offering of the Engineering Standards Committee – a forerunner of the BSI – in 1901. The importance of the First World War in establishing a national standards body cannot be overemphasised. The catalogue itself quadrupled between 1913 and 1918 and the acceleration in the annual number of publications is clearly visible. Since then, there has been a steady exponential growth; whereas the peak years of WWI in 1917 and 1918 saw just under 100 publications in the year, annual publications between 2001 and 2003 all topped 2000, representing a long run annual rate of growth of 3.7%[22]. A number of key dates in the creation of a national institution are shown in the figure. For example, the first government sponsorship dates from 1902. The BSI itself was created in 1931, by the amalgamation of the Association of British Chemical Manufacturers and the British Engineering Standards Association (BESA).

Figures 3a and 3b illustrate both cumulated publications and cumulated withdrawals and the corresponding growth of the catalogue itself. By the end of the Second World War, there were close to 1,500 standards in the catalogue. Strong expansion in the early post-war decades meant that this had increased to nearly 6,000 by 1970. The period 1970-1989 was a period of rather slower growth, but nevertheless the catalogue contained more than 10,000 in the latter year. Stronger growth has resumed over the last decade or so with the stock doubling again, with nearly 25,000 listed standards by the end of 2003. Overall, the post-war period (1948-2002) has seen a growth in the catalogue of over 5% per annum.

A final aspect of the catalogue is of importance. We have claimed that the BSI has been largely a national institution, developing standards largely of domestic origin. Certainly international standardization is largely a post-war phenomenon[23]. Figure 4, which is based upon an estimate of which standards are purely 'national' in character in the sense that they are not identical to an international standard nor do they appear to have any international equivalent. It can be seen that, although today, the overwhelming majority of standards are international, even as late as the early 1990s, well over half the catalogue consisted of national standards. The biggest share of the new standards introduced into the catalogue in the last decade have an origin in the European standards setting organisations - CEN, CENELEC, and ETSI - although some of these have their ultimate origin in the international organisations such as ISO. They represent a considerable redeployment and 'pooling' of national resources at the European level. Since the BSI is

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[22] 1918-2003

[23] There are exceptions to this general picture. The earliest truly international body is the International Electrotechnical Commision (IEC), which dates from 1906, with the support of seven countries (CEN 2002). Although the origins of International Telecommunication Union (ITU) can be traced back – as a convention - to 1865, it is only with the creation of the United Nations (UN) that truly international agencies of standardization can be said to have been created The ITU was made a specialized agency of the UN in 1947, the same year as the foundation of the International Organization for Standardization (ISO), which acts as a federation of national standards bodies.

mandated to market standards emanating from Europe, it is possible that some 'dilution' of the catalogue has occurred with some of the additional standards having little relevance for UK producers. On the other hand, it is conceivable that these standards are an efficient vehicle for technology transfer from overseas.

We can conclude this section by noting that growth in the UK appears to have been rather 'standards intensive'. This probably reflects not just the nature of the demand for standards emerging from the nature of technical change, but also from the supply of human capital, which has kept down the cost of standards development. The growth of international trade, largely based upon increasing product variety and intra-industry trade, has probably also been a factor in accelerating the demand for standards.

Having considered our measure of the output of standards by the BSI, we turn to see whether it can usefully be used in a model of UK productivity growth in the post World War II period.

An econometric model of standards and productivity

In order to produce benchmark estimates of the contribution of BSI standards to economic growth we next estimated a simple 'production function' for the whole UK economy. The period selected for the study was 1948-2002. The choice of period was dictated by the problem of data availability[24] but also in ensuring that the BSI was a truly national organisation reflecting the requirements of many sectors, not just its origins in the engineering and chemicals industries. Figure 2 is instructive in this regard, since it is noticeable that World War II had no comparable impact on the standards stock to that of the Great War of 1914-1918.

The approach we adopt here is based upon the work of Jungmittag et al (1999). This study sought however to distinguish the impact of standards from other sources of technological change – notably domestic innovation (proxied by the stock of domestic patents) and a measure of the 'import' of technology from overseas (proxied by payments to foreign companies for the use of intellectual property rights). In view of our discussion above, in which the activities of the BSI are best seen as an enabling device – *linking* innovation and human capital formation with the diffusion of technology and the development of markets, we did not consider this approach desirable. Nor did the strictly limited number of observations (54) available to us make this seem feasible[25]. Accordingly we estimated a rather more restricted production function in which conventional factors are augmented by the BSI catalogue and other 'unobservable' factors acting upon technological change.

Formally, a production function with both conventional inputs technological progress can be written as:

[24] Not least, the UK Office for National Statistics (ONS) has now produced consistent capital stock estimates for the whole period since 1948.

[25] We did however experiment with a count of UK patents granted at the US Patent Office, a plausible indicator of significant innovations. In practice, this variable turned out to be highly collinear with the standards variable. Our argument again is that both are serving as joint inputs into the process of technological diffusion.

$$Y(t) = A(t)\,[F(K(t),L(t)]$$

Where $Y(t)$ = output at time t
$K(t)$ = capital input at time t
$L(t)$ = labour input at time t
$A(t)$ = a multiplicative factor representing the level of technology

If the current level of technology is partly determined by an exogenous trend and partly by the current 'stock' of standards, then we can write:

$$Y(t) = \exp(\lambda t)\ SCI\ (t)^{\varepsilon}[F(K(t),L(t)]$$

Where: λ is an exogenous time trend representing unobservable influences on output;
ε is a parameter measuring the elasticity of output with respect to the standards stock, and
$SCI(t)$ is the standards stock at time t

If we impose both the familiar Cobb-Douglas functional form as well as constant returns to scale, then we can write the equation in terms of labour productivity:

$$Y(t)/L(t) = \exp(\lambda t)\ SCI\ (t)^{\varepsilon}\,[K(t)/L(t)]^{\alpha}$$

Where α is the elasticity of labour productivity $[Y(t)/L(t)]$ with respect to the capital-labour ratio $[K(t)/L(t)]$

Taking logarithms (denoted in lower case) we then get a simple estimating equation with a normally distributed error term, $u(t)$[26]:

$$y(t) - l(t) = a + \lambda t + \varepsilon\ sci(t) + \alpha\ [(k(t) - l(t)] + u(t) \qquad (2)$$

Figures 5 and 6 plot the observable variables in (2). Figure 5 shows the relationship in terms of levels and Figure 6 in terms of year-on-year percentage rates of growth. Two features may be noted. As both figures illustrate, an important feature of the data is that the growth of the standard stock has been very fast in comparison with productivity growth. The average annual growth rate of the standards stock over the whole period 1948-2002 was 5.1%. This compares with 2.1% and 2.2% for labour productivity and the capital-employment ratio. The similarity in the latter two numbers exemplifies one of the great 'stylised facts' of growth economics – the relative stability of the ratio of capital to output. Note that the growth in the stock of standards has been far from steady. The early post-war period shows rapid growth: between 1948 and 1973, the growth rate in the standard stock averaged close to 6% per annum; it then fell to just 3.0% up until 1990, when it accelerates again.

[26] The resulting estimating equation is similar to one for total factor productivity, used in many studies which is produced by an initial growth accounting exercise which uses factor shares to impute the contribution of capital. Here however we estimate the contribution of capital deepening (the growth in the ratio of capital to employment).

The inferential procedure adopted consisted of the well-known two step co-integrating approach, in which estimation in levels is followed by a dynamic specification using the error term (the ECM) from the first step. Standard augmented Dickey Fuller (ADF tests), not reported here, revealed that the logarithms of the stock of standards, were integrated of order one, making the co-integrating framework apposite.

Table 1, column 2 shows the results from the static regression of equation (2). These suggest strongly that a co-integrating relationship exists between the labour productivity, the capital-employment ratio, and the stock of standards. The ADF test on the residuals suggest that the null hypothesis – that there is no cointegrating relationship between the variables - can be rejected at the conventional 5% level of statistical significance. The computed long-run elasticity on the stock of standards is 0.054 – roughly a 1% increase in the stock of standards is associated with a 0.05% increase in labour productivity. There may however be more than one co-integrating association between the variables. Columns (3) and (4) of Table 1 show what happens when we ran regressions in which both the capital-employment ratio (3) and the standards stock (4) alternating as the dependent variable. At the 5% level of significance we cannot reject the null of no co-integration in either regression. However, for (3), the null of no co-integration can be rejected at the 10% level, but only narrowly.

The second stage of the analysis consisted of the dynamic specification in which the error (or ECM term) from the static regressions was entered as an additional regressor in a specification of (2) but now expressed in first differences. Here we considered a general specification in which the first difference in the logarithm of labour productivity (roughly the proportionate change) was regressed on one lag of itself, and one lag of both the first difference of the standards stock and of the capital-employment ratio. The corresponding results for the static equation (2) are reported in Table 2, column 2. While it indicates the importance of the long-run impact of standards as a determinant of labour productivity – through the ECM term described above – it also shows that the short run influence is not significant. Note that the ECM term for this specification is highly significant at the 1% level. The lack of any short run impact from standards is of course entirely consistent with both our theoretical discussion above – since standards take time to diffuse amongst a user population. Table 2 also reports some conventional diagnostic tests, which indicate no obvious signs of mis-specification[27].

The additional columns in Table 2 provide further evidence that there is a single co-integrating vector linking labour productivity with standards and the capital-employment ratio. In column (4) where the first difference in the logarithm of the stock of standards is the dependent variable, the ECM term is insignificant and there is evidence of serial correlation. In column (3), where the first difference in the logarithm of the capital-employment ratio is the dependent variable, the ECM term is significant at only 10%, and there is also evidence of mis-specification in the form of heteroscedacity.

If we accept the estimated elasticities in Table 1, column 2, then we can make some rough calculations as to the extent to which standards are associated with long run productivity growth in the UK. Although the reported elasticity – at 0.054 – may appear

[27] Further tests confirmed that the impact of standards on productivity is long-run rather than short-run in nature. These included Granger causality tests conducted on first differences and an unrestricted VAR model. Some additional results are reported in an appendix to this paper.

low, this needs to be set against the high rate of growth of the standards stock. A simple calculation reveals that standards are associated with growth in labour productivity of 0.28% per annum, or about 13% of the recorded growth over the period 1948-2002 (2.1% per annum). Great care of course needs to be in interpreting such a figure, since as we have stressed – standards should be regarded as a joint (but essential) input into the process by which new technologies are diffused, and markets are created.

Because of the changing nature of the BSI catalogue – reported in the last section - an important test for the model is its 'stability'. If there was significant 'inflation' of standards because of the internationalisation of the catalogue – and especially the pooling of standardization efforts at a European level – and this were diminishing the impact of standards, then we might expect the estimated model to perform poorly in the recent past. In fact we find no compelling evidence for such an effect. Figure 7 suggests that the model forecasts reasonably well over the period 1991-2002. Neither a conventional one step ahead forecast nor a Chow test of parameter stability suggest that the model 'breaks down' over the recent past.

Table 1

Cointegrating Regressions using Ordinary Least Squares
(sample period: 1948-2002)

(1)	(2) dependent variable =	(3) dependent variable =	(4) dependent variable =
Variable	**Log (labour productivity)**	**Log (Capital-Employment Ratio)**	**Log (Stock of Standards)**
Constant	2.064 (0.306)	-0.793 (0.671)	2.955 (2.004)
Time	0.008 (0.002)	-0.001 (0.003)	0.024 (0.009)
Log (Capital-Employment Ratio)	0.466 (0.057)	–	-0.287 (0.420)
Log (Stock of Standards)	0.054 (0.028)	-0.032 (0.046)	–
Log (labour productivity)	–	1.216 (0.149)	1.277 (0.658)
Model diagnostics			
RSS	0.017	0.045	0.408
$\hat{\sigma}$	0.018	0.030	0.089
R^2	0.997	0.994	0.985
$\bar{R}^2$	0.997	0.994	0.985
DW	0.723	0.488	0.100
t(ADF)	-4.507*	-3.696*	-2.202*
Time Period	1948 – 2002	1948 –2002	1948 – 2002

Standard Errors are in parentheses

*Lag augmentation = 1. Approximate critical values (Davidson and Mackinnon 1993 p.722, Table 20.2) are -3.84 and -4.12 at the ten and five percent level, respectively.

Table 2

General unrestricted specification of ECM models
(Sample period = 1948-2002)

(1)	(2)	(3)	(4)
Variable	**Δ Log (Labour Productivity)**	**ΔLog (Capital-Employment Ratio)**	**Δ Log (Stock of Standards)**
ECM $_{t-1}$	-0.383** (0.117)	-0.111 (0.058)	-0.031 (0.026)
Δ Log (Labour Productivity) $_{t-1}$	0.171 (0.126)	-0.453** (0.095)	-0.152 (0.121)
ΔLog (Capital-Employment Ratio) $_{t-1}$	0.375* (0.145)	0.785** (0.115)	-0.061 (0.153)
Δ Log (Stock of Standards) $_{t-1}$	-0.003 (0.093)	0.065 (0.082)	0.707** (0.097)
Constant	0.009 (0.006)	0.011* (0.005)	0.019** (0.006)
Model Diagnostics			
RSS	0.008	0.005	0.008
$\hat{\sigma}$	0.013	0.010	0.013
R^2	0.437	0.556	0.547
$\overline{R}^2$	0.390	0.519	0.502
DW	2.06	2.26	2.43
Time Period	1950 – 2002	1950 –2002	1950 – 2002
Other Model diagnostics:			
$F_{ar}(1,47)$	0.371 [0.55]	1.543 [0.22]	4.865 [0.03]*
$F_{arch}(1,46)$	0.296 [0.59]	0.802 [0.38]	0.260 [0.61]
$F_{het}(14,33)$	0.911 [0.56]	3.197 [0.00]**	1.670 [0.11]
$F_{reset}(1,47)$	0.895 [0.35]	0.442 [0.51]	1.424 [0.24]
$\chi^2_{norm}(2)$	2.663 [0.26]	2.077 [0.35]	2.128 [0.35]

Standard Errors are in parentheses
*Denotes significance at the 5% level, ** at the 1% level.

A Summary and Some Conclusions

This paper has examined the role of standards, and those created by formal standards institutions in particular. Attention was directed at the part played by these technical documents in enabling technological diffusion processes, by ameliorating associated market failures, which are increasingly being recognised as of considerable importance in the economics literature. Given that the uptake of technology is of fundamental importance for the translation of innovation into productivity growth, the attempt to assess the relationship between standards and long run productivity growth.

Standards influence the take up of technology by a population of potential users in a number of ways. Outside the case of establishing complementarities where network effects are important, they also have a role as providers of information with desirable characteristics (being government sponsored) such as credibility, also in many instances being imbued with knowledge gained through the use of technology.

Having established the potential role of standards in promoting technical change in industry, we then argue that the size of the catalogue provided by the institutional standard setter provides a possible proxy for both the output of the institution itself and its input into the wider process of productivity growth. Focusing on the post-war record in the UK, the BSI catalogue has grown extremely rapidly compared to the economy as a whole. In our view, this reflects the 'standard intensive' of much technical change, which in turn is influenced by importance of the development of information and communication technologies, the nature of the increasing international division of labour, and the skill-intensive nature of new technology.

Rather than argue for a separate and independent role for standards in promoting growth, we suggest that the development and maintenance of the standards catalogue is best seen as a 'coupling' device, linking the 'deep' drivers of productivity growth – the supply of human capital, innovation and the creation of knowledge, economies of scale etc. – with the orderly development of markets and the corresponding development of the division of labour. In summary, the institutional input from the BSI needs to be seen as an important aid to the development of markets where otherwise market failure might be important. As such, its role cannot easily be separated separated from other factors. This needs to be borne in mind in the interpretation of our statistical analysis which confirmed that, after controlling for the growth of 'conventional' inputs and exogenous influences on technology - a correlation exists between the BSI catalogue and productivity. The analysis suggests that standards were associated with around 13% of the growth of labour productivity. Since we interpret a large slide of the latter as being the result of factor accumulation, the contribution of standards to technological progress is even greater than that. We estimate the latter as contributing 1.0% per annum to UK output growth. As a proportion of this latter figure the contribution of standards is a substantial one – over one quarter.

The status of the BSI catalogue as a purely national institution has been changing significantly over the recent past and this may have a potentially important impact on this estimated relationship. Although we found no evidence for this, we note that it may be too early to evaluate these effects, especially given the rather long run nature of the impact of standards. Given that public support for standards in the UK dates from 1902, further research on the current redeployment of national standards activities will undoubtedly be important in the future.

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Data Appendix

Output – Gross value added at 2000 basic prices (chained volume measure). Source: ONS Blue Book Time series data as at April 2004

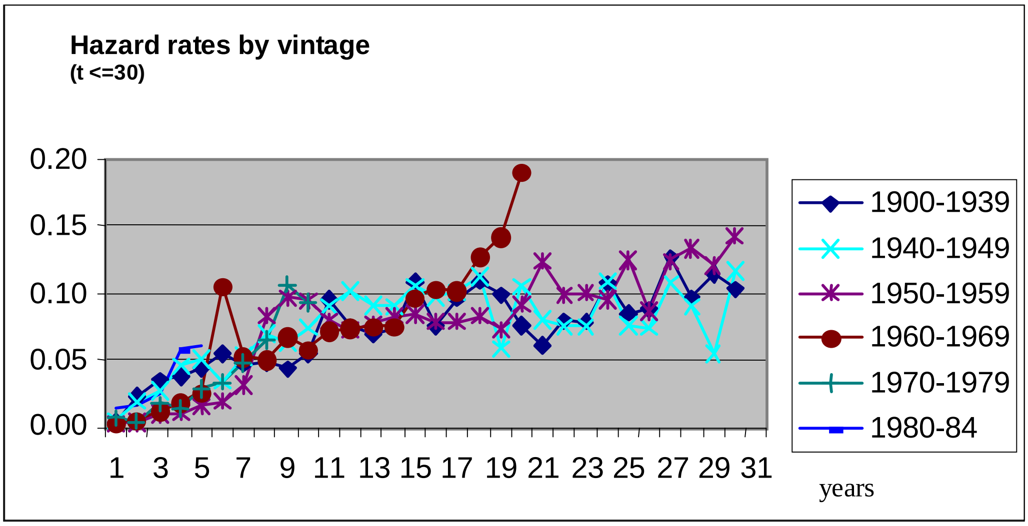
Capital Stock – Gross capital stock (volume measure) of total capital stock excluding dwellings; from ONS Capital stock time series data as at April 2004

Employment – This was constructed from two series. 1948-1959 C.Feinstein (1972) and workforce jobs (both exclude HM armed forces) – Labour Market Trends (ONS) time series website.

SCI – the 'standards catalogue index', based upon end of year stocks, calculated from Equation 1 in the paper. This was estimated for the period 1901-1984 from the *BSI History Book* (kindly supplied by Mary Yates of the BSI Library), and from 1985-2003 from *PERINORM©* - a database produced by a consortium of BSI, AFNOR, and DIN. The latter allowed for exact calculation of equation (1) in the text. While a complete count of publications was possible for the early period, only a proportion of total withdrawals was possible. A brief description of how the remainder was estimated is provided below.

The Retirement Dates of Standards

The need to estimate the retirement dates of certain standards led us to look at retirement patterns. The following chart – which 'pools' annual 'vintages' of standards by decades shows empirical probabilities of the likelihood of a standard being retired in year t given that it has survived up to the beginning of year t. This is the so-called *hazard rate*. The picture suggests that the hazard rate increases steadily up to about 10 years and then is relatively constant at around 10-11%. The pattern is rather similar for the vintages of different decades, and we in fact imposed a constant pattern for all standards for which we had no firm retirement dates from the 'History Book'. Experiments with altering these hazard rates had little important impact on our estimates of the 'state' of the BSI Catalogue in any particular year. The actual hazard rates used were: 0-2 years: 0.008; 2-5 years: 0.027; 5-10 years: 0.059; 10-20 years: 0.093; 20-30 years: 0.102; 30+ years: 0.100.



Estimation Appendix

To validate the results from the Engle-Granger procedure, we tested the annual data for cointegration using the maximum likelihood approach of Johansen (1988, 1991). We estimated a first-order vector-autoregression (VAR) in *y-l*, *sci* and *k-l* and a constant entered unrestrictedly. Our findings are recorded in Table 3. There is a single cointegrating vector on the basis of the maximum eigenvalue and trace test statistics at the 1 per cent level. The values of the resulting cointegrating vector are (standard errors in parentheses)

$$\log(\text{Labour Productivity}) = \underset{(0.059)}{0.589} \log(\text{Capital-Employment Ratio}) + \underset{(0.031)}{0.173} \log(\text{Standards})$$

Both the estimated long-run capital-employment ratio and standards elasticities have the expected signs, but the latter is particularly large in magnitude. It needs to be remembered that, in not allowing for other factors explaining technological change that this particular model and the estimated elasticities are not comparable with those reported in the body of the paper which incorporate an exogenous time trend.

Table 3: Cointegration statistics, (1948-2002)

Eigenvalue	Log likelihood	rank *r*
	441.551	0
0.4307	456.761	1
0.2358	464.021	2
0.0463	465.301	3

H_0: ‘rank = r’	Max-Eigen Statistic	99%	Trace Statistic	99%
r <= 0	30.42**	25.52	47.50**	35.65
r <= 1	14.52*	18.63	17.08*	20.04
r <= 2	2.56	6.65	2.56	6.65

Standardised β' eigenvectors				Standardised α eigenvectors			
	y - l	*k - l*	*sci*		*i = 1*	*i = 2*	*i = 3*
i =1	1.000	-0.589	-0.173	*y - l*	-0.345	0.003	-0.003
i =2	-0.263	1.000	-6.169	*k - l*	-0.253	-0.113	0.001
i =3	7.170	-0.385	1.000	*sci*	0.301	-0.109	-0.003

Note:
** Denotes significance at the 1% level, * at the 5% level.

Figures

Figure 1a

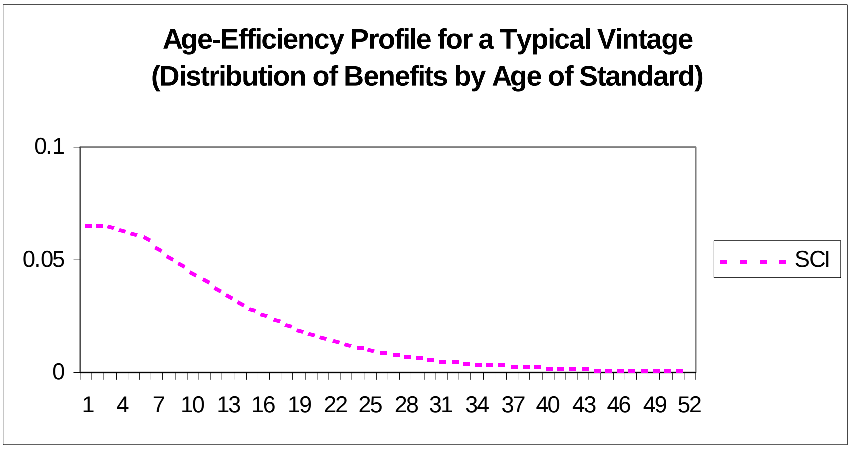


Figure 1b

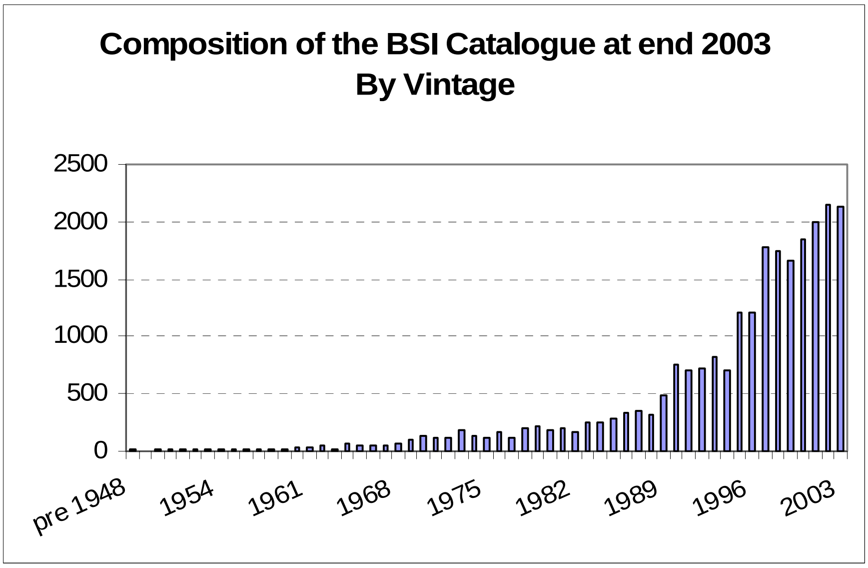


Figure 2

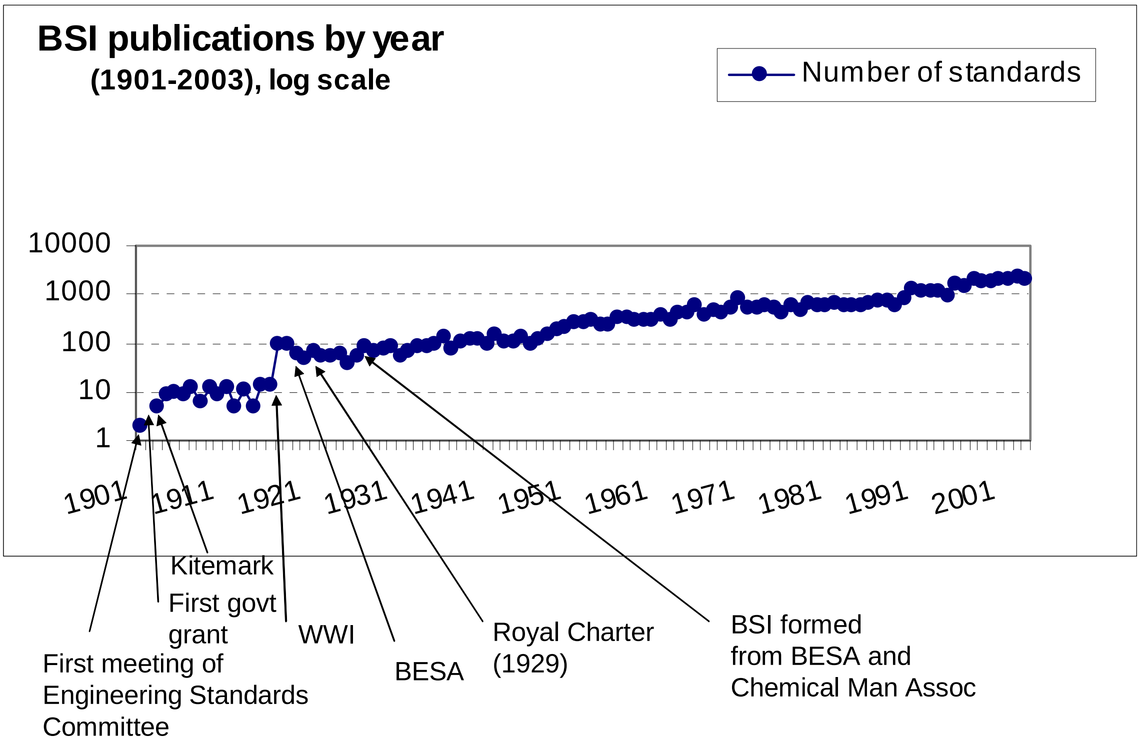

BSI publications by year
(1901-2003), log scale
Number of standards
10000
1000
100
10
1
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
Kitemark
First govt grant
WWI
First meeting of Engineering Standards Committee
BESA
Royal Charter (1929)
BSI formed from BESA and Chemical Man Assoc

Figure 3a

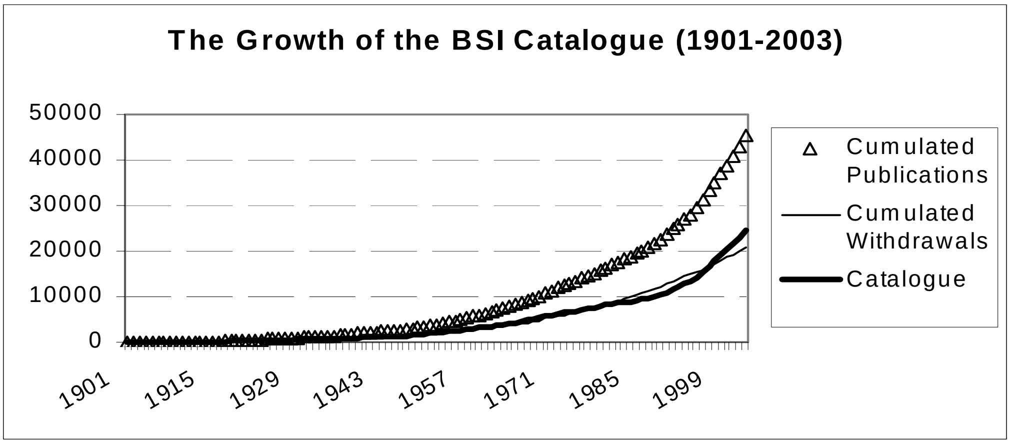


Figure 3b

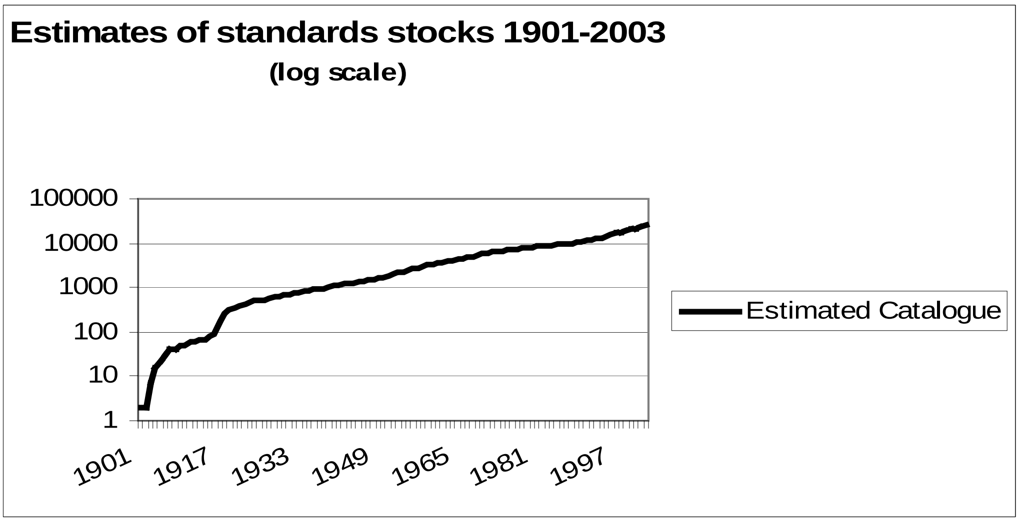


Figure 4

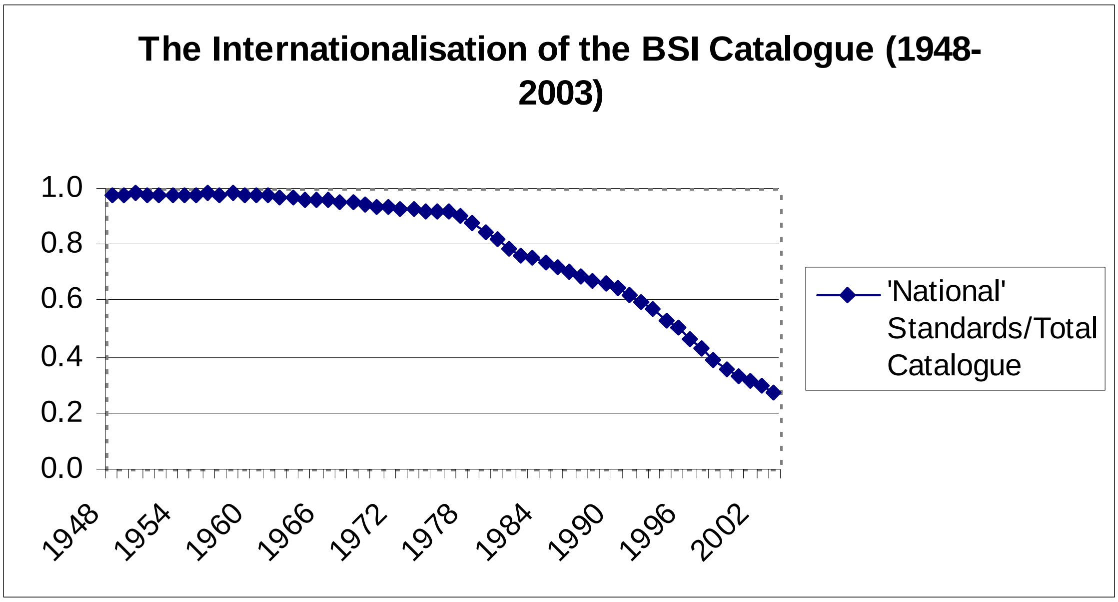

The Internationalisation of the BSI Catalogue (1948-2003)
1.0
0.8
0.6
0.4
0.2
0.0
1948
1954
1960
1966
1972
1978
1984
1990
1996
2002
'National' Standards/Total Catalogue

Figure 5

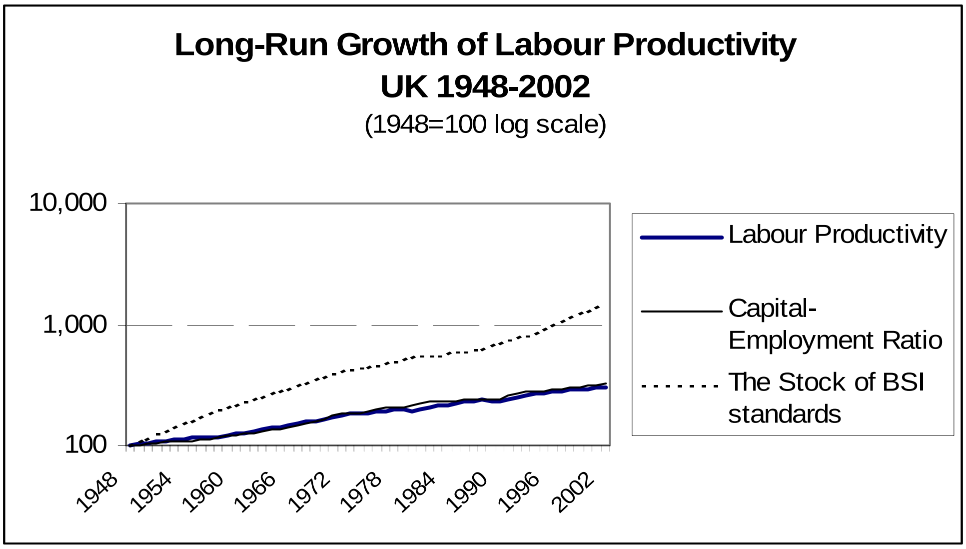


Figure 6

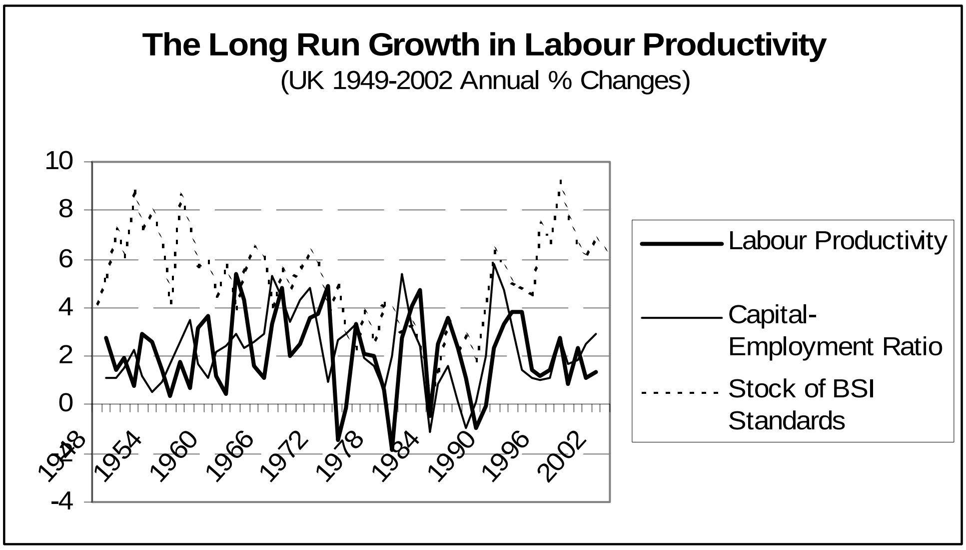
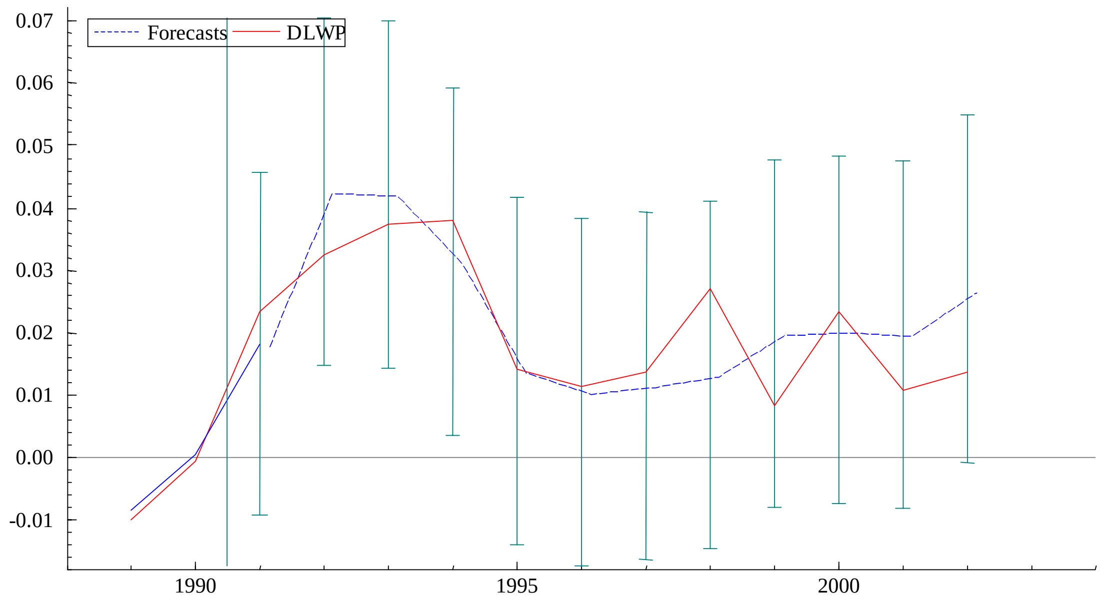


Figure 7


Forecasts
DLWP
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
1990
1995
2000