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STANDARD SETTING ORGANIZATIONS, INFORMATION FLOWS AND BUSINESS STRATEGIES: AN EMPIRICAL INVESTIGATION

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Standard Setting Organizations, Information Flows and Business Strategies: An Empirical Investigation¶

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Abstract

The paper investigates the link between standards, business strategy and innovation, based upon a factor analysis of the stated 'context' for innovation contained in the 2012-2014 UK Innovation Survey (UKIS). The analysis reveals a distinction between pro-active 'entrepreneurial' strategies and reactive and 'defensive' strategies, as well as firms, although regarded in the survey as innovation 'active' have no clear innovation based objective. We combine this classification with sectoral indicators of the significance of standards to investigate how firms deliver these strategies. We find that, in addition to the important role played by the type of innovation strategy, standards have a significant impact not only on the extensive margin of R&D expenditures, but also on the likelihood that firms will invest in related complementary investments, notably in training and design. We test these propositions with a specific UKIS question on the value that firms put on standards. The positive impact that standards have on the acquisition of innovation related assets suggest that, on balance, the impact of standards has significant pro-competitive effects on an innovation system.

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1. Introduction

Firm level strategies which are founded upon innovation depend for their ultimate impact on many of the wider aspects of sectoral, national and global innovation systems within which they are formulated. Beyond the protection of intellectual property, these wider aspects include (for example) institutionalized processes of standardization within standard setting organizations (SSOs). While there are now many studies which explore microeconomic aspects of such processes, including their interaction with intellectual property protection, these have been limited in the main to the exploration of issues arising in a small number of sectors, and we still lack evidence regarding the impact of SSO activity on wider systems of innovation by considering aggregations of related standards. Further investigation along these lines is important because of the potential for SSO activity to generate aspects of 'systems failure' in which monopolistic elements become entrenched and creative competition and entry (and hence possibly innovation) inhibited. While a number of studies have been conducted at the macroeconomic or national level and which clearly point to positive contributions running from standards to innovation and productivity, these have been unable to shed much light on the patterns and mechanisms involved. In this contribution we seek evidence from a combination of the United Kingdom Innovation Survey (UKIS) with sectoral level data of SSO activity in general to determine how such activity influences innovation based strategy. Our findings suggest that this source of knowledge has discernible impacts on firms' innovation strategies, especially in relation to the creation of the in-house capabilities needed to deliver the strategy, and where the extensive margin of such investments among firms has considerable relevance for economic policy. We corroborate the inferences made in this part of the paper with data (also from UKIS) on the value that firms place on standards as a source of information.

The paper is organized as follows. The next section considers briefly how standardization can be seen from an innovation system perspective. Section 3 discusses the sectoral dimension of institutionalized standardization activity and its implications for knowledge flows which are integral to the empirical analysis, which is then further motivated in Section 4 by a consideration of the implications of variation in the extent of codified knowledge provided by standards. Section 5 then outlines the empirical methodology and data used. Section 6 discusses the results. Section 7 offers a summary and conclusion.

2. Standardization in an Innovation System

Standardization takes many forms and fulfils several well established economic functions within innovation systems, but quite generally requires the adoption of a common specification for a product or process. That occurring within an organization has of course been integral to many firm level strategies aimed at creating value.[1] Our main interest here

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[1] A purely 'internal' standardizing strategy was of course central to the eventual superior productivity of the factory system which eventually culminated in the development of the Model T at the Ford Motor Company (see for example Hounshell (1984) ; a recent formal economic model distinguishing 'standardizing firms' from 'innovators' can be found in Acemoglu et al (2012).

however is in those standardization processes which require coordination and collaboration across firms and which thereby involve the disclosure of intellectual property, some of which is then incorporated within a codified knowledge base which may both structure and inform business strategy. Such processes thereby form a close relationship to other types of collaboration involving knowledge exchange, including research consortia and patent pools, both cases in which there is considerable debate about the impact of not only upon innovation but also upon competition[2]. Given the strong sectoral element to the importance of SSO activity that is known to exist and discussed further below, our contribution to this question is to consider the impact on strategy of the resultant distribution in knowledge bases. However, in distinction to many earlier studies, we consider differences not just in the type of innovation (e.g. product, process or organizational) but explore differences in the purpose of the innovation which may be genuinely entrepreneurial, but may also be more defensive, as a rational response for example, to global competition and entry or a response to domestic regulation.

While decentralized choices (i.e. 'markets') may provide one form of the coordination required to create a standard, possibly through the dominance, or at least leadership, of individual firms, there is now a long literature which suggests that often they do not – one reason being the difficulty in excluding other firms from using a standard, potentially rendering the resource commitments in developing the standard unprofitable in more fragmented market structures, where no individual firm or small group of firms has sufficient market power to create a so-called *de facto* standard. But where the 'prize' of setting a dominant standard is large enough, there may be sufficient to generate a 'standards war' with a variety of possible outcomes (Shapiro and Varian 1999).

An alternative path to standardization, in which a committee, following the formal rules of an SSO, achieves consensus among its members, has also proved an important component of innovation systems, especially where network effects are present and the mutual objective of substantial increases in the size of the market outweighs simple competitive considerations. By far the most frequently analyzed examples of such a path have been in the development of ICT, where there are very many committees dedicated to the creation of common 'technology platforms', i.e. an aggregation of standards which achieve inter-operability between different elements within the platform and within which firms agree to compete (see for example Besen and Farrell 1994, Tassey 2017).

Individual standards developed by SSOs promote 'order' within and between markets, and while it may be argued that this is opposed to innovation which implies disruption to the status quo, it is now clear that both economic theory and the empirical evidence have advanced sufficiently to recognise that the reality is considerably more nuanced. In terms of theoretical developments for example, evolutionary theories predict that the creation of order in product markets stimulates process innovation (e.g. Mueller and Tilton (1969), Gort

[2] For example, the activities of SSOs are considered by the OECD Competition Committee. OECD (2010) states that "By bringing together different players in an industry, the standard setting process provides an opportunity for collusion, deception and strategy about which regulators must be vigilant and proactive", noting *inter alia* the potential for standardization processes to be subject to 'patent ambushes'.

and Klepper (1982)), while much of the game theoretic literature has been concerned with the compatibility and inter-operability provided through standardization and which by extending the market and/or clearly defining the market encourages forward commitments to R&D and other sunk cost investments related to innovation (Farrell and Saloner 1985). Empirical studies have also tended (at least on balance) to indicate positive impacts of standardization activity on innovation; for example there is now evidence from several countries linking standardization activity to aggregate productivity growth, initially for Germany (Blind et al 1999 and Blind et al 2011), but with broadly similar results for the UK, (Temple et al, 2005, chapter 2), Australia (Standards Australia 2007), Canada (Standards Council of Canada 2007) and France (AFNOR 2009). Moreover key surveys of the literature examining the relationship between standards and innovation point to many different mechanisms at work, only some of which have been explored empirically (see for example discussions in Swann 2010, Blind 2009, Swann and Lambert 2017). These surveys point to the importance of standardization activity as 'catalytic' in character, in stimulating the complementarities between different agents and institutions within an innovation system.

Hawkins (2017) has recently extended the idea that individual standards promote 'order' to consider the more general 'stabilizing' influence of institutionalized standardization activity within an innovation system. On this view, standardization needs to be afforded a structural position rather than simply an enabling mechanism within a system, thereby addressing a postulated bias in existing analysis towards the potentially destabilizing influence of innovation linked to innovative entry and entrepreneurship. Although SSO activity takes many specific forms, we may develop this idea further by considering the following more or less stable characteristics constituted by such activity, conditioning the process of knowledge accumulation through standards more generally and hence, we argue, firm level decentralised strategic responses to evolving technological opportunities.

(1) The standards created are 'open' in character, which can be defined in various overlapping ways (West 2007), but following Simcoe (2006) by the fact that any firm is able to *use* them "on reasonably equal terms" thereby making a distinction from openness in terms of access to the creation of standards, which may be restricted in various ways but in any event almost always by the costs involved in participation. Although these costs may well be lower for larger firms, Blind and Manglesdorff (2013) using evidence from the electrical engineering and machinery sectors, show that small and medium sized firms often participate indirectly through the formation of alliances. How effective such mechanisms are in ensuring competition, is of course central to the policy evaluation of any innovation system.

(2) The 'order' created by the aggregation of standards – along well defined technological trajectories where firms compete within a set of related standards - impacts upon sunk cost forward commitments, not just in R&D, but also in terms of other innovation related expenditures and cumulative further learning. This makes SSO activity an important contributor to the commercialization of innovation and the stabilizing influence of 'industrialization' (see the diagram in Hawkins 2017).

(3) SSOs are typically comprised of technical committees in which members pool various types of intellectual property. The mutual disclosure of intellectual property within technical

committees has created a considerable literature on the economic consequences of intellectual property deemed as essential for adherence to the standard, possibly protected by IPR, as in the case of so-called 'standard essential patents' (SEPs). In theory, this can lead to several pathological outcomes. These include the potential for opportunism where essential IP is only revealed when standardizing firms have already committed to certain paths of development, and the licence fee may be able to extract some of the costs associated with switching to an alternative. However, rule bound SSO activity as well as repeated interactions may be able to lessen this threat in the form of *ex ante* commitments such as proposed by for example by Swanson and Baumol (2005), Lerner and Tirole (2015). In practice, the types of commitment proposed therein are difficult to implement and SSOs generally involve less clear-cut FRAND commitments[3]. For a recent survey see Comino et al 2018. A further potential problem is that of royalty 'stacking' where royalty payments on SEPs which are vertically related are detrimental both to producer and user surpluses (Cournot 1838/1897, Shapiro 2001), because one monopolists supplying to another fails to take into account the impact on each other's profits in charging the monopoly price.

(4) The process of pooling intellectual property within an SSO also constitutes a significant learning mechanism in its own right, and there is significant potential for knowledge spillovers to be internalized among participants and for rents to be obtained through repeated interaction with other firms and the formation of a network. Inter alia, firms may learn ways of incorporating standardization into their business strategies.

These characteristics of SSO activity operate through each of the dimensions of an innovation system as identified by Malerba (2005) – i.e. as a knowledge base acting over a particular 'technological domain' with specific collective learning processes, as a forum for 'actors and networks', and of course as an 'institution' acting, as we have seen, as a constraint on business behavior (North 1990), but importantly, one which is capable of co-evolution with other institutions, for example those represented by intellectual property rights. But SSO activity is not uniformly distributed across national or global systems of innovation, but has a strong sectoral dimension, embracing specific product groups and user-producer interfaces which arguably has implications for the knowledge base of these sectors. Our approach in the empirical part of this paper is to use this sectoral dimension, to which we now turn, to examine the implications for innovation.

3. The Sectoral Dimension of SSO activity

The empirical analysis in this paper is partly based on the contention that the knowledge made available as both codified and open through SSO activity varies considerably across sectors, partly driven by and in co-evolution with, the historical evolution of technological opportunities, as well as by various differences in the configuration of supply and demand.

On the demand side, with reference to both existing and potential or expected demand, the benefits from standardization stem from the opportunities made possible through

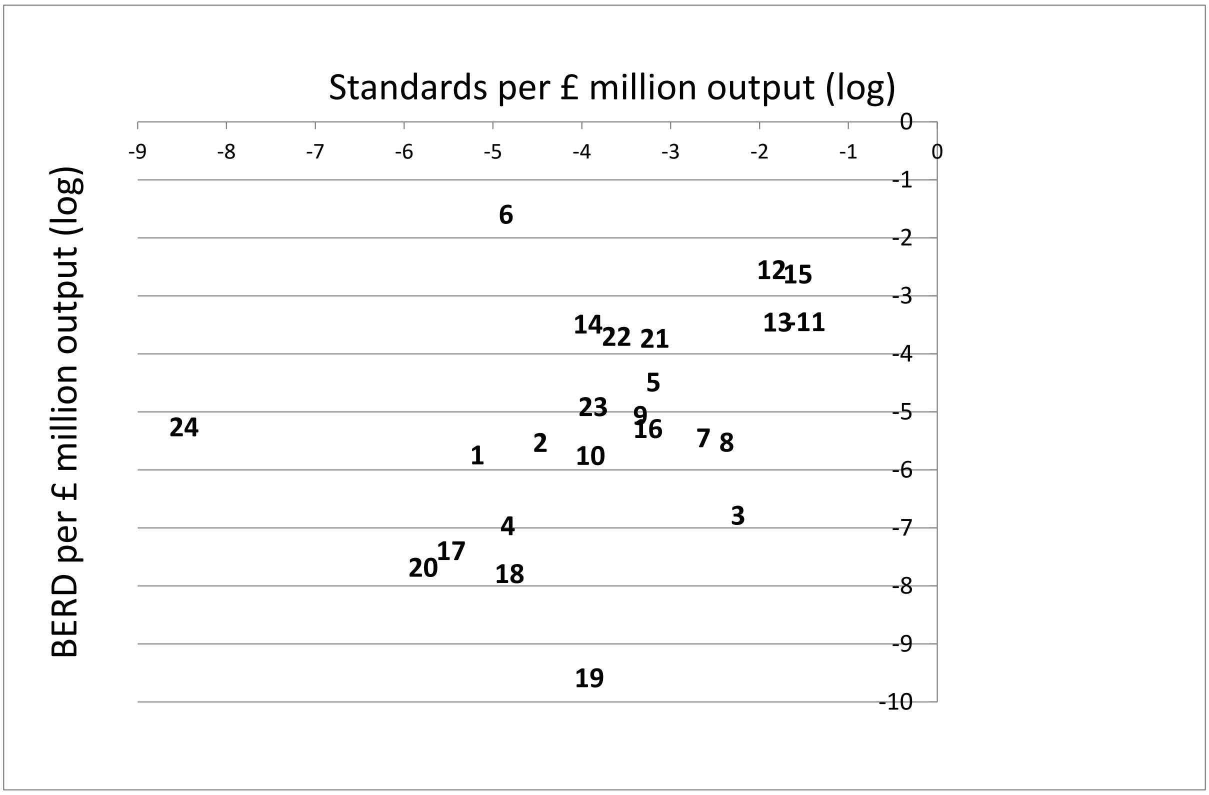
[3] A commitment to licence on 'fair, reasonable and non-discriminatory terms'.

technological change, with powerful motivations arising in specific competitive contexts. These include the potential for significant networking effects, where the common objective of a larger market dominates concerns about intellectual property disclosure. This has proved particularly important in ICT where patenting has not prevented standardization through 'technology platforms' where powerful positions for particular firms or coalitions may nevertheless be generated, especially where patents can be obtained.

From the supply side, since participation is costly in terms of resource commitments, but the availability of an open standard as we have defined it, is not, makes standards themselves something strongly resembling a public good, although of course implementation is never costless. Participation may however, as noted above, be motivated by the benefits of being part of a network and/or by being able to generate rents through the contribution of proprietary technology. Here the complexity of the technology may be an important determining factor. Moreover, there is almost certainly a role for cumulative causation, with strong SSO activity in a sector generating, possibly through lower overheads, lower cost participation and rent seeking based on successful standardization. Indeed, historically it is possible to distinguish several waves of standardization through SSOs, as identified for example by Steinmueller (2017) who describes the strong link between the development of mass production in what is sometimes termed the 'Second Industrial Revolution' and the creation of what he terms 'reference standards' dealing for example, with units of measurement of mass, length, or time or providing ways of assessing the properties of materials, activities closely aligned with engineering and instrumentation. While much of this activity was of course carried out 'in-house', with dominant integrated manufacturing firms providing purely proprietary standards for suppliers and users, oligopolistic structures were also able to generate rents from collaborative efforts, and which allowed for the pooling of intellectual property on the basis of 'mutually assured destruction' in the event of litigation (U.S. Federal Trade Commission [2003, ch. 2, pp. 30–31] as modelled in Schmalansee (2009)), who observes the potential for repeated interaction to resolve possible prisoner's dilemmas. Later waves of standardization owed much to the regulation of these powerful positions in both the US and Europe, notably in computing and telecommunications, which opened up technological opportunities based upon 'modularity' in input-output interfaces in complex systems (Baldwin and Clark 2004). This arguably opened opportunities for business strategies to attempt to manage the process of the standardization needed and achieve a degree of industrial leadership through efforts to maintain and promote particular design configurations. Intellectual property rights have undoubtedly played a large part and even been integral to this process and have spawned a considerable literature. Further, the complexity of systems has made possible the contribution to standardization of firms which are dedicated to R&D and rely more heavily on royalty payments. The impact of the changing composition of participation in standards development has been both theoretically modelled (of interest because of the potential for opportunistic behavior or royalty stacking mentioned above) but there is little empirical evidence indicating the significance of royalty payments as a significant barrier to standards use or as a motivator for participation (Lambert and Temple 2015).

These waves of standardization have left their mark on the sectoral distribution of knowledge generated by SSOs. Figure 1 shows a comparison between aggregate business expenditure on R&D across 24 UK and the stock of relevant standards available to producers[4] (both normalized by sectoral outputs). While the two are clearly positively correlated, certain manufacturing sectors notably 12 (electrical equipment), 15 (other transport – including aerospace), 13 (machinery and equipment), 11 (computing and electronic products) stand out as generating both much R&D and standards activity, while 21 (telecommunications) and 22 (computing and IT services) stand out in the same way in services.

FIGURE 1:
Sectoral Distribution of R&D and Stocks of Standards (UK 2012)



Given these sectoral differences in access to 'open' standards, there are of course important questions as to how this impacts within a national system of innovation, at the core of which are business strategies aimed at innovation. Since, as we have argued, that standardization is a collaborative activity in which firms have proprietary stakes in the intellectual property disclosed in the process, a fundamental question concerns whether an environment rich in this type of knowledge has discernible impacts not only on the likelihood that a firm will adopt a strategy focused on innovation, but also upon the pattern of its related investments. Other things being equal, the knowledge being pooled will be that which does least harm to each firm's competitive position, and a conception of

[4] The measure is described in more detail below while the sectors by SIC code can be found in the appendix

standardization as providing public goods may be an accurate one[5]. However, as we have seen, this outcome may be modified or indeed overturned by the ability of firms to leverage the value of its IP through standardization and making an innovation based strategy for competing firms more expensive or difficult to achieve. Consequently a major part of the empirical analysis of this paper focuses on the extensive margin of innovation related investments. However before passing onto the empirical analysis, we consider it important to consider in more detail the relationship between the standards environment, its information content, and business strategies aimed at innovation.

4. Business Strategies and the Information Content of Standards

The central question examined in this paper is whether the sectoral dimension to committee based SSO activity is associated with discernible differences in business strategies, and if so which elements?

As we use the concept here, business strategies are founded upon rational decision-making in which strategies are formulated with clear objectives in mind, made in the light of a firm's understanding of its own capabilities and of the particular competitive environment in which it is situated (see for example Kay, 1993). Adding an assumption that firms are aiming to increase their value in the long-run, the approach suggests that a business strategy has three main elements:

- first, an objective which increases value added for the firm (*a value proposition*);
- second the means for *delivering* that path;
- and third, a means for *capturing* the value created and the conditions for its *sustainability* into the longer term

We consider each in turn, noting the potential impact of sectoral variations in the stock of codified knowledge made available through standards.

Innovation is of course only one possible route for increasing value which may entail for example, engaging in strategic and/or entry deterring behaviour. However in terms of the framework adopted here a more fundamental starting point is the objective of the strategy – typically involving an increase the value added obtained from its operations. In fact however, many studies of innovation based strategy have begun with a consideration of the *form* taken by innovation, e.g. in terms of product, process or organizational innovation (see for example Battisti and Stoneman (2008) in the case of the UK) or whether they are 'simple' or 'complex' embracing more than one type of innovation simultaneously (see for example Tavassoli and Karlsson (2016). There is no strong reason to suppose that a strong

[5] Paradigmatic may be the knowledge generated by what is known as the measurement infrastructure discussed in King et al (2017) and where the knowledge used in standardization may considerably reduce the fixed cost element in R&D projects, and help firms avoid duplicative elements.

knowledge base in the form of standards favours either product or process innovation, but plausibly it may encourage incremental product innovation rather than novel product innovation, where in the absence of standards the supplier-user interface may suffer from information asymmetries, while the 'order' created in product markets may be an important stimulus to more radical *process* innovation, as suggested by life cycle theorists. While it is usual to associate innovation with pro-active profit oriented strategies in the Schumpeterian tradition, it is also possible to distinguish these from what might be termed 'defensive' innovations – those undertaken in response to a changing environment. Examples of the former include responses to increasing international competition, or in achieving a response to changes in a regulatory regime in which case standards may offer a lower cost way of meeting the changing business requirements, although of course regulatory capture by participants in SSOs is a possibility, which would raise the relative costs of non-participants. Although receiving little attention in the innovation literature, the distinction between these two motivations has intermittently been applied in the case of the UK (Lamfalussy 1959, 1963, Eltis 1996) and has arisen more generally in the debate about the impact of globalization and competition from developing economies and especially China on the labour markets of developed economies trade where the nature of the competition induces reactive defensive innovation (e.g. Wood 1994, van Reenen 2011).

In our view, the form taken by innovation should correctly be considered as part of the process of delivering the value proposition. In addition, achieving value through innovation requires mechanisms for reconfiguring internal capabilities to deliver the strategic source of value. Here, much policy interest focuses on R&D and increasingly on effective forms of collaboration. As far as R&D is concerned, the first question is whether a strong standards knowledge base reduces fixed cost elements of projects and hence works on the extensive margin of R&D, and secondly whether it enables collaborative behaviour by reducing transactions costs. Strong codified knowledge bases should assist collaboration(s), whether with the science base – or with competitors or suppliers.

However delivery may require other inputs outside of R&D stemming from a more general reconfiguration of internal capabilities and the acquisition of innovation related (complementary) inputs. Here, there is now a considerable volume of evidence that this may require further innovation in managerial techniques or other organizational methods for successful delivery (for the UK, Battisti and Stoneman (2010), or more generally Frenz and Lambert 2012, Tavasolli and Karlsson 2016). Our own earlier work, based on a survey of firms on the use of standards suggested that use extended beyond product specifications, and that they are widely used not only in research and innovation, but also for workforce development and training (Lambert and Temple, 2015).

Innovation by itself is seldom adequate for the *capture* of value by individual firms and firm level business strategies must consider and incorporate the *management* of intellectual property into that strategy. In the 'profiting from innovation' (PFI) framework for example, strategies are shaped by an 'appropriability regime' (Teece 1986) – i.e. the protection of an innovation allowed by formal intellectual property rights regime (patents, trademarks etc.) and by the extent to which there are 'natural' barriers to imitation – e.g. in terms of the complexity of the product and the tacitness of the technology. Without such natural barriers or when IPR are strong, firms need to consider their asset position in relation to the innovation – in particular are there strengths in assets which are complementary to the innovation and where competitor firms are in a better position to supply so-called ‘bottleneck’ inputs? Arguably, the existence of standards enables the acquisition of these complementary inputs at more competitive prices by reducing information asymmetries and the potential for bottlenecks.

The discussion suggests the importance for empirical analysis to consider explicitly the explicit aim(s) of innovation strategies and to distinguish between those which are pro-active and more defensive aims. Arguably, a facilitation of the latter is an important aspect of the ‘order’ provided by standards within an innovation system.

Further the discussion makes it clear that there is no clear-cut set of hypotheses regarding the relationship between the strength of the standards environment and the pattern of delivery. A strong standards environment should however enable the accumulation of knowledge which directly serves the ‘core’ element in an innovation strategy which delivers competitive advantage – often associated with R&D and workforce skills - while reducing the potential for complementary inputs, e.g. in marketing, to act as bottlenecks. We now consider the empirical approach and the data employed.

5. Data and Empirical Methodology

Our main source of data for the empirical analysis comes from the ninth version of the UK Innovation Survey (the ninth) covering the period 2012-2014. The surveys provide considerable evidence regarding both innovation outcomes (product versus process innovation and the degree of novelty involved) as well as innovation related commitments to R&D, innovation related training, etc. Among other information sought in the Survey is one directly relevant to the purpose of a strategy, termed the ‘context for innovation’. It is to our knowledge rather rarely used in survey use, but as discussed above clarity as to purpose is essential for an articulated innovation based strategy. The survey is also well constructed to provide information regarding methods for delivering the aims of the strategy, covering not only product, process or organizational innovation, whether offering novelty but also covering various inputs related to the innovation. The latter include not only R&D (either internally or externally sourced) but also other means of technology acquisition (including cooperation). The data are particularly well suited to an examination of the extensive margins of these innovation related commitments of resources.

In order to measure broad sectoral differences in both technological opportunities and appropriability conditions (as suggested by the PFI framework), the survey data have been supplemented by data for 24 sectors, covering aggregate business spending on R&D in 2012, and a summary measure of appropriability. The latter is a measure of the extent to which firms feel that there exist effective means of value capture. This was generated from the previous version (2010-2012) of the survey, which (unlike the 2012-14 survey) asked a question regarding the “effectiveness” of various methods “for maintaining or increasing the competitiveness of product and process introduced during 2010 to 2012?” These methods embraced both formal means of protection (patents, trademarks, design rights, copyright, trademarks) and informal (lead time advantages, complexity and secrecy). These were then amalgamated into a single measures of appropriability based on sectoral averages of individual row means. Matched data from sectors to the underlying survey was available for 11,787 business units (henceforth 'firms').

Although the surveys contain limited direct evidence regarding the role of standards (but see below), we were able to combine the survey with a specially constructed set of standards data. These allowed us to examine the impact of the system wide 'standards environment' on innovation strategies. In order to obtain useful measures of this environment facing firms when formulating strategies, we used the PERINORM[6] standards database to generate data for the sectors in both manufacturing and services. The analysis employed two measures of the availability of codified information – first a simple count of the relevant standards available to producer firms in each sector as well as a plausible measure of the currency of those standards – the year after which half these stocks of standards were published (the median year of the stock)[7].

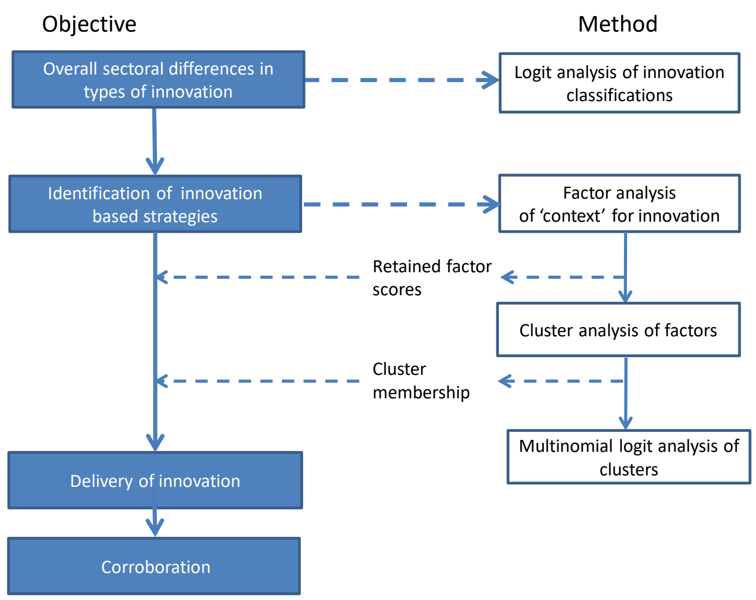
A schemata for the methodology adopted is shown in Figure 1. The framework of the survey filters those units who are regarded as being 'active' in the field of innovation; inter alia this may include firms who are searching for an innovation but are not actually innovators or who report an innovation, but have no clear strategy founded upon innovation. In our view the binary concept of innovation underpinning the Survey is too broad to identify a strategy in which innovation is the lead element. Our approach necessitates first of all therefore the identification of a coherent innovation based strategy. As argued above, this requires that innovation has the clear objective of value creation. In order to meet this challenge, we use a factor analysis of the survey question regarding the 'context' for innovation, which distinguishes between the importance of 11 mechanisms for value creation[8], e.g. 'entering new markets', 'improving the quality of goods and services' or 'improving health and safety' (for the full list see table 1, while further details can be found in the data appendix). The purpose of the factor analysis is not only to reduce the dimensionality of these data but also in the first instance to provide a means of identifying firms which, because of the intensity of their belief that innovation would lead to increased value, could genuinely be described as possessing an innovation based strategy. Furthermore, there is potential for further factors to provide a classification scheme for such strategies. We also used a cluster analysis of factor scores to establish possible unobserved heterogeneity. Regression analysis of these factor scores, making allowance for this, was then employed in the first instance to determine whether access to a large and/or up-to-date (or mature) set of standards had discernible impacts on the mix between the different strategies identified.

[6] PERINORM is a database of worldwide standards maintained by a consortium of the BSI, Deutsches Institut für Normung (DIN), and Association Française de Normalisation (AFNOR).

[7] The use of 'counts of standards' in empirical research now has a longish record beginning with Swann et al (1996), in the context of trade competitiveness. Swann also introduced the median age of the relevant stock in Temple et al (2005). See also Jungmittag et al (1999), CEBR (2015), Spencer and Temple (2016).

[8] The actual survey has twelve mechanisms but our data aggregates the need to meet health and environmental regulation.

Figure 2
Methodology for Empirical Analysis



Both the factor scores and cluster membership were then used in the subsequent analysis of the strategy delivery mechanisms. For delivery we consider the sectoral patterns in terms of (i) the type of innovation (ii) the extensive margins of innovation related inputs, (iii) cooperation with external partners. For each of these, the Innovation Survey is particularly well suited[9].

[9] Unfortunately, this version of the survey was not of direct use for an examination of the informational role that standards may play in helping firms to manage their intellectual property.

Although direct reference to standards in the survey is limited, it does however contain one question of direct relevance to our assessment of SSO activity. This is Question 16, again with sample restricted to firms recorded as active in some aspect of innovation asks respondents to rate “how important to this business's innovation activities was information from” [one of] a variety of sources?” One of the twelve sources is that of “technical, industry or service standards.” While first of all internal sources of information and then those generated by customers, suppliers and competitors are typically considered the most important, previous surveys have found that standards both rival the last named and are more important than other sources[10]. Inevitably, the pattern of responses is going to reflect the decisions made by individual firms as well as the extent of SSO activity which suggests that we can employ the pattern of responses *indirectly* to test inferences regarding the sectoral patterns revealed in the preceding analysis. So for example if higher levels of SSO activity are associated with more product innovation, we would expect, *ceteris paribus,* a product innovator to rate this information rather higher than a process innovator. In our view, this approach provides an important source of confirmatory evidence for our analysis.

6. Results

Although the main objective is to examine sectoral differences in innovation strategies, possible only for a sample of firms considered by the survey as ‘active’ in innovation we checked initially for sectoral differences in the pattern of innovation across the entire sample, using the Schumpeterian distinction between product and process innovation and also whether the innovation is considered by the respondent to be ‘novel’ (new to ‘market’ in the case of product innovation or new to the ‘industry’ in the case of process innovation). In addition, the survey allows for innovation in managerial and organizational or marketing methods (so-called ‘broader innovation’). Full results of a logistic regression on each of these binary variables are presented in the appendix (Table A3), but they confirm the significance in our data of sectoral influences running from technological opportunities and appropriability, to innovation activity and innovation itself, although the results found are clearly stronger for product than for process innovation and for goods rather more than services. Moreover the stock of standards available to producers also provides a positive predictor for each of the measures of innovation, and is statistically significant for product innovation and so-called ‘broader’ innovation. However, the median year of the standard stock (indicating the currency of that stock) is significantly and negatively related to the extent of product innovation, suggesting that it a large but mature standards stock enhances innovative product differentiation by reducing transaction costs. Since our sample is however restricted to firms who have responded positively to some activity related to innovation, our next objective, to which we now turn, was to identify firms which both appear in this sub-sample (as innovation active) but also possess an innovation based strategy for increasing the value of the firm.

[10] Lambert and Temple (2015) find for example that looking at the two previous waves of the survey, 44.7% of respondents found technical industry or service standards to be of ‘medium’ or ‘high’ importance.

Factor/Cluster Analysis of Innovation Strategies

To enable the identification of innovation based strategies we used a factor analysis of a binary version of responses to question 15 of the 2012-2014 survey which looks at the context for innovation as described above[11]; this allowed for a more parsimonious representation of the 11 categories in the survey, which evidently overlap in various ways. Indeed, the Kaiser-Meyer-Okin measure of overall sampling variance of above 0.9 suggested that the sum of partial correlations was large enough for factor analysis to be reliable. The results from a factor analysis based upon iterated principal components of the responses are shown in Table 1, which indicates the rotated factor loadings using a standard varimax rotation of the original variable space for two retained (but still orthogonal) factors. Reassuringly, the largely inclusive option of 'increasing value added' displays a relatively low level of uniqueness, while at the other end, innovation resulting from the need to replace 'outdated' products or processes displays relatively low commonality.

It can be seen that the first factor, explains 55% of the variance when rotated, driven largely by intensity of value objectives which seek increased market share or new markets through a 'pro-active' context – an increased range of goods or improved quality. The second factor, which explains 45% of the rotated variance has high loadings on cost reduction, improving health or safety or meeting regulatory requirements. Our interpretation of the second factor is that it provides a measure of more 'defensive' or at any rate 'reactive' innovation strategies. Note that with this classification there is no direct link to the type (product or process) innovation: For example, 'entering new markets', which loads very highly on the first factor could be achieved either through product or process innovation.

Further light was shed on interpretation of the factors by use of a cluster analysis of the standardized factor scores (using k-means) in order to detect potential but unobserved heterogeneity in the data. This suggested the presence of three similarly sized clusters, as illustrated in Figure 3, which shows both means and standard deviations of the standardized factor scores for each cluster. A significant number of firms identified in cluster 1 (nearly 25% of the total sample) do not on this evidence possess (by our classification) any clearly articulated innovation strategy, confirmed by the large number in this group reporting neither a product nor a process innovation, although many do report wider (organizational or managerial) innovation. However our main interest is in differences between innovation strategies and here the cluster analysis suggests a potentially important distinction between

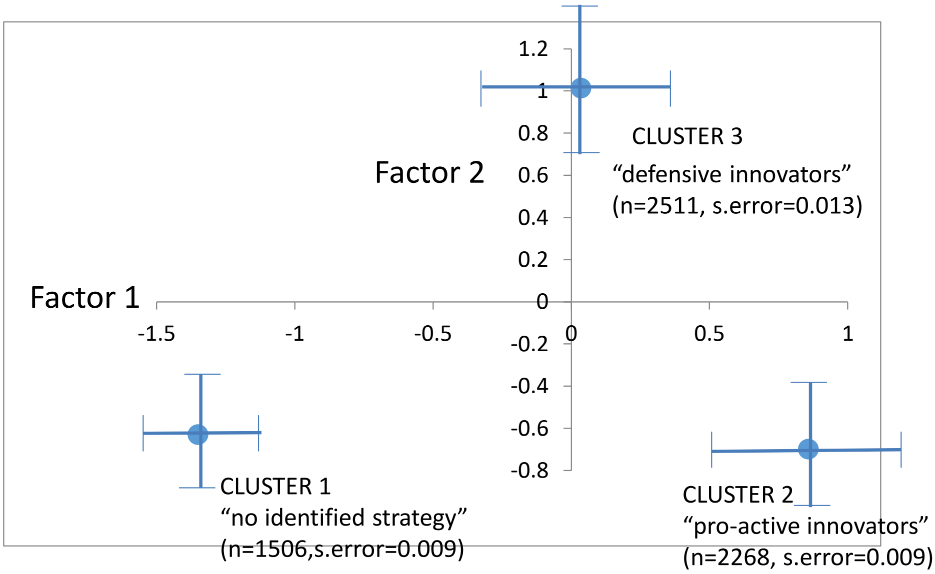
[11] Precisely, if the If the particular context for the innovation was rated by the respondent as being of medium or high importance than it scores 1, 0 otherwise.

TABLE 1:
Rotated Factor Loadings
(IPF/Orthogonal Varimax Rotation)

	Identifier	Factor 1	Factor 2	Uniqueness
Increasing range of goods or services	RANGE	0.8566	0.2523	0.2026
Entering new markets	NEWMARKET	0.7773	0.1993	0.3561
Increasing market share	SHARE	0.8175	0.2892	0.2481
Improving quality of goods or services	QUAL	0.7191	0.5974	0.1261
Improving flexibility for producing goods or services	FLEX	0.5843	0.6095	0.2871
Improving capacity for producing goods or service	CAP	0.5170	0.6234	0.3440
Increasing value added	VALUE	0.7040	0.5077	0.2466
Reducing costs per unit produced or provided	COST	0.4452	0.6635	0.3616
Improving health and safety or reducing environmental impacts	ENVHEALTH	0.2286	0.7688	0.3567
Meeting regulatory requirements (including standards)	REG	0.2837	0.6985	0.4316
Replacing outdated products or processes	REPLACE	0.3858	0.5671	0.5295

innovators in cluster 2 who do so proactively (scoring high on factor 1 with a mean of 0.86 but who are below the mean in terms of factor 2) and those strategies which may be reacting to changing competitive or regulatory pressures (high on factor 2 but close to the average in terms of factor 1). As reported more fully in Table A3 of the appendix, a multinomial logit analysis using our sectoral data did not indicate very powerful sectoral differences in the probabilities of a firm being in any of the three clusters, although the standard intensity of a sector did significantly predict in favour of a firm being a member of the ‘proactive’ cluster 2. In terms of other variables of interest, shown in Table A5.

FIGURE 3:
Cluster Analysis of Standardized Factor Scores
(indicating means and standard deviations)



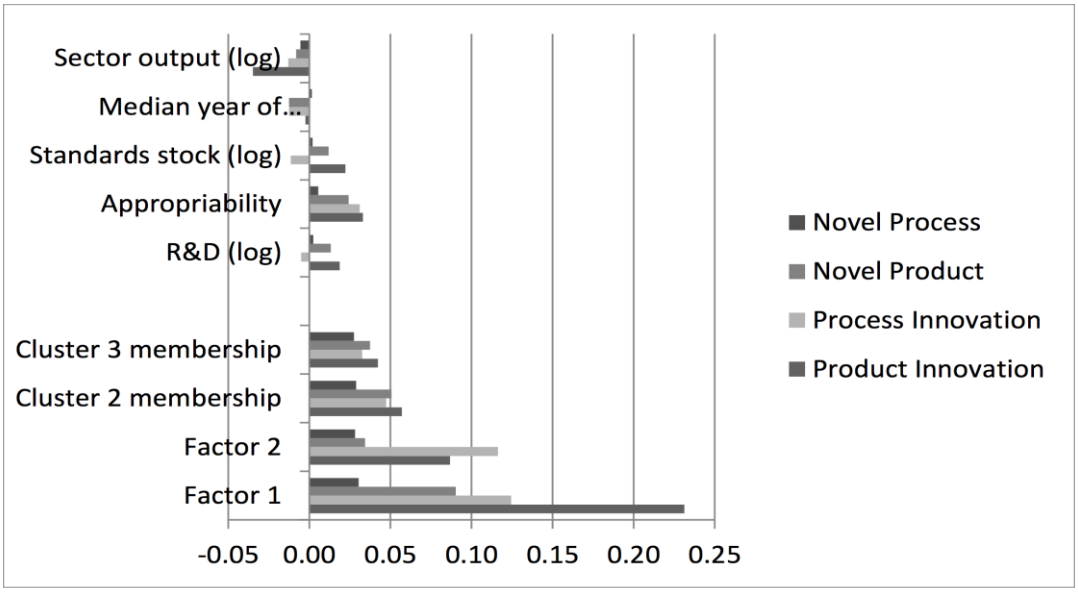
Delivery

Delivering a strategy requires comprehending and specifying the means or inputs for achieving the desired outcome(s). As noted above, this embraces a number of activities, not just the type of innovation but also providing for the capabilities required and determining the extent of collaboration and cooperation with other firms. Such activities are all highly information intensive and it is therefore likely that the differential impact of sectors with a rich stock of standards will have an impact on the ability and willingness of firms to undertake risky investments related to innovation. Accordingly, figures 3-6 show results from a set of logistic regressions indicating the marginal probabilities for a sequence of binary variables covering patterns of strategy delivery. The results have been categorized into the type of innovation (product or process), the acquisition of technology (R&D, licensing, and cooperation), embodied and software related inputs, and other innovation related inputs (design, training and marketing). For comparative purposes the marginal probabilities for the explanatory variables have been multiplied by their respective standard deviations.

Figure 4 emphasizes the relevance of both the individual factor scores for the likelihood of observing any particular type of innovation; both are statistically significant across all four types of innovation reported, although the relative importance of the two factors do confirm that the second factor is relatively more important in explaining process innovation, whether novel or not, consistent with the hypothesis that this factor is picking up relatively more defensive innovation aimed at cutting costs or meeting regulations in a cost efficient manner.

Over and above the individual factor scores cluster membership also conveys additional information, with positive impacts on both product and process innovation arising from membership of *both* clusters of innovators. By contrast, Figure 3 indicates that comparatively small amounts of further information are conveyed by the sector level variables: although they are mainly correctly signed, only our appropriability measure achieves statistical significance and only then in the case of novel product innovation[12].

FIGURE 4: Innovation Type
(weighted marginal probabilities)

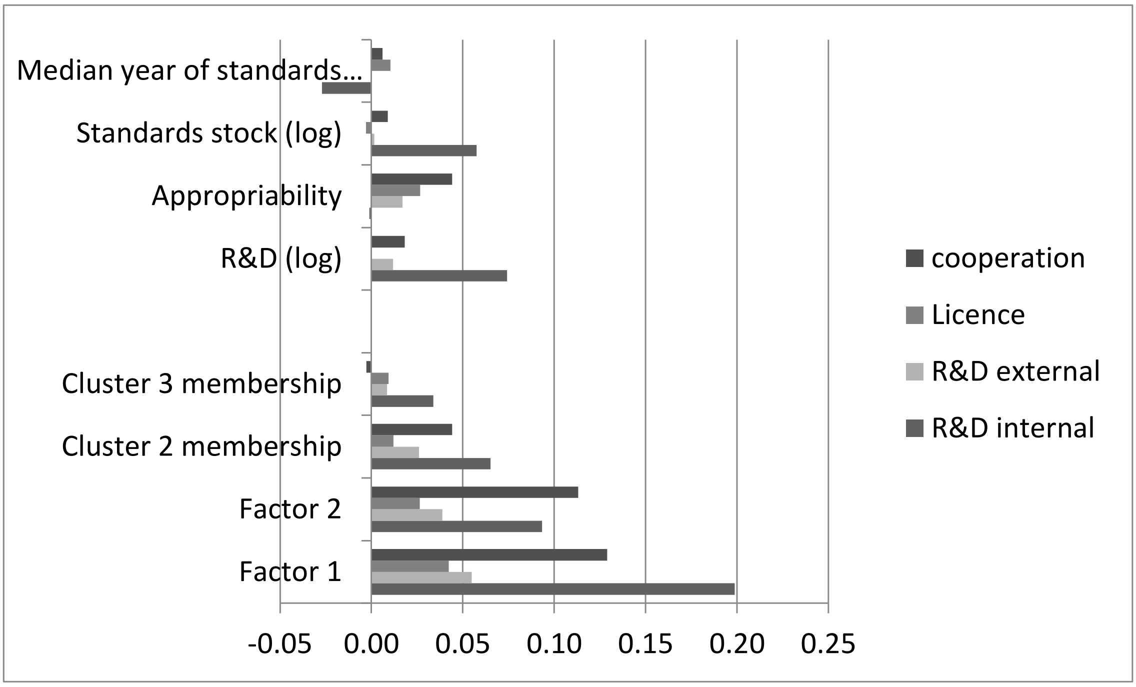


Sectoral differences is however considerably more significant when we go on to consider innovation related inputs and whether the firm did or did not engage in the activity. Figure 5 shows the weighted marginal probabilities for the acquisition of technological inputs, i.e. R&D (both internal and external) or acquiring a licence for intellectual property; the figure also includes cooperation as a simple binary variable (whether or not the firm engaged in the said activity). For internal R&D - for which Factor 1 is considerably more important than Factor 2 – being a member of cluster 2 - one of the ‘proactive innovators’ – is also estimated to have a probability nearly 0.07 higher than a ‘defensive’ innovator. As far as technology acquisition is concerned, an interesting feature of the estimates is that Factor 2 is almost as important in predicting cooperation.

[12] In addition to those indicated in the figure, sector level variables include the log of sectoral output levels, to capture the ‘intensity’ with which standards are developed or R&D pursued.

Sectoral influences beyond aggregate levels of R&D expenditures are also important in explaining the external margin when it comes to internal (if not externally sourced) R&D. As shown, when conditioned on the factor scores and cluster membership, an increase in the size of the standard stock available to a firm, equivalent to one standard deviation is associated with an increase in the probability of a firm conducting its own R&D of over 0.05. However a more up-to-date standards stock has a small and marginally significant negative association, consistent with the idea that the codified knowledge stock has a cumulative effect, with a large number of well understood standards plausibly helping to lower the fixed costs of R&D.

FIGURE 5: Technology Acquisition
(weighted marginal probabilities)



Figures 6 and 7 show the results for various inputs generally considered as complementary to each other in developing and delivering innovation.

Figure 6 shows marginal probabilities for investments in equipment, computers, and software. Notably, factor 2 is rather more important for these ‘embodied’ investments than factor 1, consistent with the relatively greater emphasis on process innovation. As far as standards are concerned, large and up-to-date standard stocks are important for computing equipment and software. The sectoral influences on equipment investment related to the investment are however quite different: notably, a more elderly standards stock is positively related to investment in other types of capital equipment.

Figure 6: Equipment and Software
(weighted marginal probabilities)

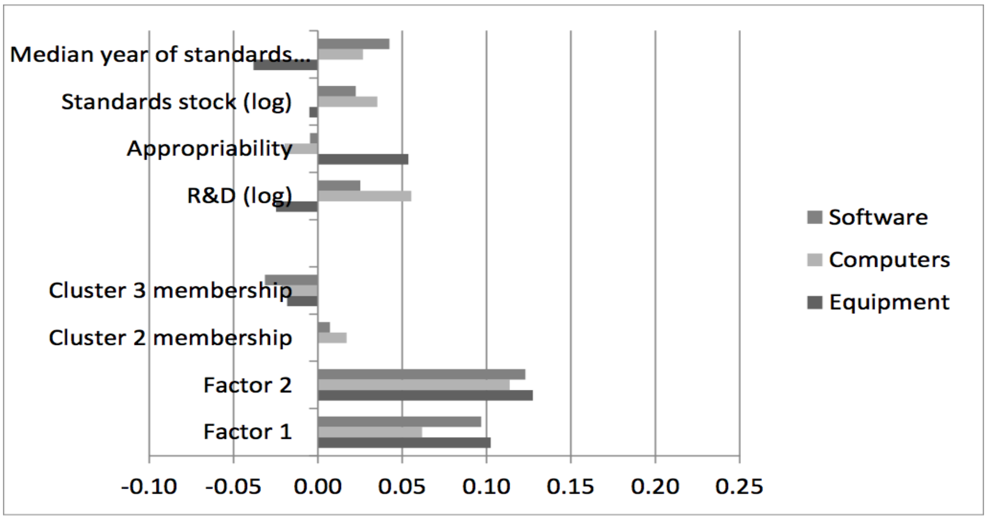


Figure 7: Design, Training and Marketing
(weighted marginal probabilities)

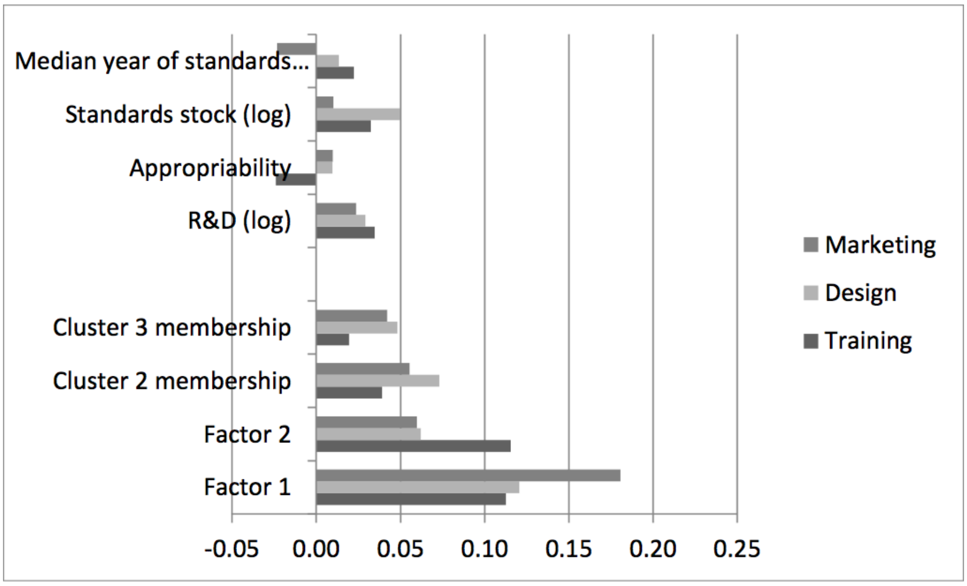


Figure 7 shows the corresponding results for training, design and marketing, where the role of the two factors reverses in the case of design and marketing inputs with factor 1 the more important influence, plausibly reflecting the greater requirement for complementary inputs in the case of pro-active product development strategies.

Corroborative Evidence from the Innovation Survey

To summarize the results so far, we have found that an essential underpinning of an innovation led strategy – a strong value proposition – is an important determinant of the extensive margin of innovation related inputs. After controlling for this we have found that sectoral factors are also important. We should expect these inferences to be reflected in the value that individual firms place on the information contained in standards and in the experiments reported here we attempt to predict the pattern of responses to the specific question in the Innovation Survey which refers to industry standards: specifically question 16(k) asks as to "how important to this business's innovation activities was information from technical, industry or service standards?" In this regard, and over and above sectoral influences, we should expect that answers also reflect the actual decisions taken. Our estimates above suggest that both factors describing strategic aims should be very important in the determination of answers to this question, but that in addition, those businesses which use internal resources for R&D and those which invest in training and design related to the innovation should place increased value on standards as a source of information.

Table 2 presents some representative results from logistic analysis of question 16(k) in which the dependent variable conflates answers which rate the information contained as of 'medium' or 'high' importance as being equal to one (as opposed to 'low' or 'non-applicable', equal to zero). Four results sets are reported here[13]. Result set (1) uses just the factor scores and our sectoral data as explanatory variables. Result set (2) introduces contributors to the delivery of the strategy, while (3) and (4) also add various types of control variable at the firm level.

All the results confirm that both factors are highly significant but that factor 2 is, in this and the other results reported, more important than factor1, reflecting the importance of standards for firms *reacting* through innovation to changes in their competitive environment.

For cooperation, the striking finding is that standards are especially valued not through cooperation as such (the impact is estimated as positive but statistically insignificant) but varies positively and significantly with the *number* of cooperative partners, which is consistent with standards being significant facilitators of communication amongst more diverse networks of innovating firms.

As far as firm level controls are concerned, we find that neither firm size nor whether it operates in an international market appear to be significant (over and above their impact operating via firm level strategy). We also find that while the percentage of employees with a science degree is an important predictor of the value placed on standards, there is little evidence that other types of degree are important.

[13] Dummies representing cluster dummies were never significant and results which include these are not reported here.

TABLE 2:
The Informational Value of Standards

	(1) marginal probability	standard error	sig.	(2) marginal probability	standard error	sig.	(3) marginal probability	standard error	sig.	(4) marginal probability	standard error	sig.
Factor 1	0.157	0.009	***	0.134	0.010	***	0.132	0.010	***	0.140	0.012	***
Factor 2	0.220	0.008	***	0.207	0.008	***	0.207	0.008	***	0.214	0.010	***
R&D (log)	0.025	0.010	**	0.019	0.011	*	0.019	0.011	*	0.010	0.012	
Appropriability	-0.347	0.238		-0.422	0.244	*	-0.460	0.246	*	-0.340	0.282	
Standards stock (log)	0.026	0.010	***	0.023	0.010	**	0.024	0.010	**	0.014	0.012	
Median year of standards stock	-0.004	0.007		-0.005	0.007		-0.004	0.007		-0.008	0.008	
Sector output (log)	-0.031	0.015	**	-0.027	0.016	*	-0.028	0.016	*	-0.012	0.018	
Product Innovator				-0.020	0.019		-0.020	0.019		-0.021	0.022	
Process Innovator				-0.021	0.018		-0.021	0.018		-0.025	0.021	
Novel product				-0.009	0.023		-0.011	0.023		-0.015	0.026	
Novel Process				0.037	0.031		0.037	0.031		0.013	0.035	
Internal R&D				0.033	0.018	*	0.031	0.019		0.031	0.022	
External R&D				0.003	0.023		0.002	0.023		-0.003	0.027	
Equipment				0.000	0.018		-0.001	0.018		-0.004	0.021	
Computer				0.011	0.020		0.011	0.020		-0.004	0.023	
Software				-0.039	0.020	**	-0.038	0.020	*	-0.017	0.023	
Licence				0.035	0.027		0.035	0.027		0.038	0.031	
Training				0.074	0.018	***	0.075	0.018	***	0.085	0.021	***
Design				0.053	0.019	***	0.050	0.019	***	0.050	0.022	**
Marketing				0.004	0.017		0.003	0.017		0.004	0.020	
Cooperation				0.000	0.022		-0.001	0.022		0.011	0.026	
Number of linkages				0.022	0.004	***	0.023	0.004	***	0.017	0.005	***
Size (log number of employees)							0.000	0.000		0.000	0.000	
Firm Operates in an International Market							0.025	0.017		0.007	0.020	
% of employees with science degree										0.002	0.000	***
% of employee with other degree										0.001	0.001	
Additional Firm Level Controls	NO			NO			YES			YES		
(SIZE, International Market [YES/NO])	NO			NO			YES			YES		
(Science Degree/Other Degree (%))	NO						NO			YES		
Number of obs	4,964			4,951			4,951			3,709		
LR chi2	1,139.920			1,258.980			1,262.200			968.920		
Prob > chi2	0.000		***	0.000 ***			0.000 ***			0.000 ***		
Pseudo R2	0.172			0.191			0.191			0.195		

7. Discussion and Conclusion

Despite the plethora of studies of standardization activity both at a micro and aggregate national levels, there is still considerable scope for understanding how aggregates of standards specifying constrained paths of learning function within an innovation system, especially in relation to their impact on competition and innovation. For various reasons, including cumulative causation, the standardization that operates through committees creating open standards has a strong sectoral dimension which is exploited in the empirical analysis in this paper.

The paper has further argued that the role played by standards in the innovation system can better be understood by placing innovation through a filter created by a consideration of business strategy. This suggested systematically considering the specific objectives of innovation in terms of value creation, for which there is useful evidence from the UK Innovation Survey. The resultant factor analysis suggested a clear demarcation between those businesses which appeared to have an articulated strategy and those which, for a variety of possible reasons, do not. Scores on both the first two factors identified suggested that they were both important for understanding the innovation survey data. Interpretation of the factors was assisted by the clustering of firms along these dimensions, which suggested a useful demarcation could be drawn between pro-active forms of innovation, perhaps more closely aligned with the Schumpeterian entrepreneur, and those where motivation is more accurately defined as 'defensive' or 'reactive' in character. From this perspective, the type of innovation as a means of delivering the objective of the strategy was found to be less relevant than it would seem from much of the extant literature.

This conceptual division of strategy proved particularly interesting when it came to the pattern of innovation related to the acquisition of innovation related inputs. Interestingly, while entrepreneurial strategies are significantly more important in explaining the extensive margin for internal R&D, defensive innovation seem to be as important as the more proactive strategies in understanding the extent of both externally sourced R&D and cooperative activity; moreover this factor was actually rather more important in the of determination of investments which involve embodied inputs, as well as being more important in predicting training related expenditures.

As far as understanding the role of standards within innovation systems is concerned, our analysis allowed for not only the extent of codified information available through standards, but also in terms of how up-to-date it was. This established that, at sector level, the significance of standards varied considerably, consistent with the significance of sectoral systems of innovation suggested by Malerba (2002). In general we found large and significant impacts on the extensive margin of some but not all innovation related investments; these included not only investments in internal R&D, but also notably in design and training. As might be expected, the currency of the available standards displayed no consistent pattern – but up to date standards were found to be important for investments involving design and software while a stock with rather older standards was important for investments in physical (but not computing) equipment. Moreover the pattern of results was largely confirmed by the predictive success of the model in explaining the pattern of attitudes to the value placed on information provided by standards.

From a policy perspective, much of the recent literature on SSOs has been focused on the potential for SSO activity to generate anti-competitive results, entrenching incumbents or allowing opportunistic behaviour by firms which rely heavily on royalty payments. The evidence presented in this paper does not support either of these possibilities when aggregate behavior is considered, and while case studies point to the relevance of such behaviour, these are we suggest, inconsistent with the estimated increase in the extensive margins.

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DATA APPENDIX

TABLE A1
The Sectoral Distribution of Standards

		Business Expenditure on R&D (intra-mural £m 2010)	Output at basic prices (£m 2010)	Stock of Relevant Standards 2012	Median Year of Standards Stock (2012)
SECTOR					
1 Mining and oil,gas extraction	2007 SIC	152	46,699	264	2006
2 Food and beverages, tobacco	05-09	306	75,866	871	2004
3 Textiles, clothing, leather	10-11	11	9,560	1015	2003
4 Wood, paper, printing, recording	13-15	28	29,127	232	2006
5 chemicals inc petroleum ref exc pharma	16-18	739	64,570	2644	2005
6 Pharmaceuticals	19-20	4673	22,671	177	2009
7 Rubber and plastic	21	80	18,284	1316	2006
8 Non-metallic mineral products	22	56	13,808	1291	2007
9 Basic metals	23	114	17,742	628	2003
10 Metal products	24	93	28,844	581	2008
11 Manufacture of computer, electronic and optical products	25	647	20,002	4582	2009
12 Manufacture of electrical equipment	26	987	12,446	1927	2008
13 Manufacture of machinery and equipment n.e.c.	27	809	25,169	4165	2007
14 Manufacture of motor vehicles, trailers and semi-trailers	28	1237	39,853	782	2010
15 Manufacture of other transport equipment	29	1668	22,661	4716	2006
16 Other Manufacturing, repair	30	136	26,529	1022	2009
17 Electricity, gas,water, sewerage	31-33	60	95,880	403	2009
18 Sewerage,Waste and Waste Management	35-36	11	26,127	212	2007
19 Building and Construction	37-39	14	200,199	3990	2008
20 Transport and Distribution	41-43	194	413,363	1270	2007
21 Telecommunications	5-47;49-53	1129	46,505	1935	2008
22 Computing and IT services	61	1526	60,795	1646	2010
23 Scientific and Technical Services	62-63	618	82,614	1719	2007
24 Other Business Services	71-75	583	110,433	23	2010
	77-78,80-82				
Source:		ONS	Eurostat supply tables	Perinorm/own estimates	Perinorm/own estimates

TABLE A2

Summary Data

	Whole Sample			Restricted Sample[1]		
	No of obs	Mean	Standard Deviation	No of obs	Mean	Standard Deviation
Innovator	15091	0.288	0.453	5017	0.529	0.499
Product Innovator	15091	0.223	0.416	5017	0.429	0.495
Process Innovator	15091	0.161	0.368	5017	0.304	0.460
Novel Product	15091	0.083	0.276	5017	0.181	0.385
Novel Process	15091	0.038	0.191	5017	0.084	0.277
Product Goods	15091	0.136	0.343	5017	0.297	0.457
Product Service	15091	0.136	0.342	5017	0.239	0.426
Internal R&D	15091	0.208	0.406	5017	0.454	0.498
External R&D	14690	0.064	0.245	5004	0.140	0.347
Equipment	14691	0.131	0.337	5005	0.288	0.453
Computer Equipment	14697	0.252	0.434	5007	0.418	0.493
Software	14696	0.297	0.457	5008	0.507	0.500
Licence	14689	0.046	0.210	5004	0.100	0.300
Training	14693	0.167	0.373	5007	0.336	0.472
Design	14693	0.137	0.344	5007	0.303	0.460
Marketing	14695	0.221	0.415	5007	0.440	0.496
Cooperation (YES/NO)	15091	0.278	0.448	5017	0.641	0.480
Number of cooperative linkages	14687	0.890	1.824	5003	2.065	2.338
Cluster 1				5017	0.232	0.422
Cluster 2				5017	0.341	0.474
Cluster 3				5017	0.427	0.495
Aggregate R&D (log)	12141	5.389	1.172	5017	5.393	1.165
Appropriability	14737	0.176	0.087	5017	0.205	0.094
Standards Stock (log)	15091	6.550	1.360	5017	6.838	1.383
Median Year of stock	15091	2007.7	1.694	5017	2007.3	1.372

1. Sample for which factor/cluster analysis is performed, i.e. conditional on firms regarded as being active in innovation. Availablility of aggregate R&D data and appropriability were further sources of sample attrition.

Table A3

Logistic analysis of Sectoral Patterns of Innovation

Logistic Regression

Dependent Variable	Innovator?			Product innovator			Process Innovator			Broad Innovator		
	marginal probability	standard error	sig.	marginal probability	standard error	sig.	marginal probability	standard error	sig.	marginal probability	standard error	sig.
Variable												
R&D (log)	0.016	0.006	***	0.023	0.005	***	0.003	0.005		0.024	0.007	***
Appropriability	0.620	0.142	***	0.449	0.125	***	0.383	0.106	***	0.310	0.167	*
Standards stock (log)	0.010	0.006	*	0.014	0.005	***	0.001	0.004		0.017	0.007	**
Median year of standards stock	-0.012	0.004	***	-0.010	0.003	***	-0.005	0.003	*	-0.004	0.005	
Sector output (log)	-0.031	0.009	***	-0.032	0.008	***	-0.016	0.007	**	-0.034	0.010	***
No of obs	11787			11787			11787				11787	
LR	575.96			585.32			271.63				260.52	
Pr (Chi2)	0.000		***	0.000		***	0.000		***		0.000	***
Pseudo R2	0.04			0.05			0.03				0.02	

	Novel product			Novel Process			Goods			Services		
Variable	marginal pro	standard err	sig.	marginal pro	standard err	sig.	marginal pro	standard err	sig.	marginal pro	standard err	sig.
R&D (log)	0.012	0.003	***	0.002	0.002		0.007	0.004	*	0.011	0.004	**
Appropriability	0.259	0.068	***	0.088	0.048	*	0.504	0.094	***	0.078	0.102	
Standards stock (log)	0.007	0.003	**	0.002	0.002		0.019	0.004	***	0.006	0.004	
Median year of standards stock	-0.006	0.002	***	0.000	0.001		-0.014	0.003	***	0.010	0.003	***
Sector output (log)	-0.011	0.004	**	-0.007	0.003	**	-0.020	0.006	***	-0.006	0.006	
No of obs	11787			11787			11787			11787		
LR	428.74			119.39			825.07			62.180		
Pr (Chi2)	0		***	0		***	0		***	0.000		
Pseudo R2	0.0607			0.03			0.0804			0.016		

Note: * significant at 10% ** significant at 5% *** significant at 1%

TABLE A4

Multinomial Logit Analysis of Clusters

Base cluster 1

	Relative Risk Ratios	standard error	sig.
CLUSTER 2			
R&D (log)	1.128	0.072	*
Appropriability	12.819	18.737	*
Standards stock (log)	1.144	0.067	**
Median year of standards stock	0.975	0.039	
Sector output (log)	0.818	0.073	**
CLUSTER 3			
R&D (log)	1.015	0.062	
Appropriability	9.769	13.722	
Standards stock (log)	1.088	0.061	
Median year of standards stock	0.984	0.038	
Sector output (log)	0.746	0.064	***
No of obs	5017		
LR	246.03		
Pr (Chi2)	0		
Pseudo R2	0.0229		

Note: * significant at 10% ** significant at 5% *** significant at 1%

TABLE A5
Strategy Delivery: Type of Innovation

Logistic Regression

Dependent Variable	*Product* marginal probability	standard error	sig.	*Process* marginal probability	standard error	sig.	*Novel Product* marginal probability	standard error	sig.	*Novel Process* marginal probability	standard error	
Variable												
Factor 1	0.231	0.015	***	0.124	0.012	***	0.090	0.009	***	0.030	0.006	***
Factor 2	0.087	0.014	***	0.116	0.012	***	0.034	0.008	***	0.028	0.006	***
Cluster 2 membership	0.119	0.042	***	0.098	0.038	***	0.105	0.037	***	0.060	0.027	**
Cluster 3 membership	0.088	0.044	**	0.068	0.039	*	0.078	0.033	**	0.057	0.025	**
R&D (log)	0.016	0.011		-0.004	0.009		0.011	0.006	**	0.002	0.004	
Appropriability	0.366	0.257		0.345	0.200	*	0.269	0.127	**	0.061	0.079	
Standards stock (log)	0.017	0.010		-0.009	0.008		0.009	0.006		0.002	0.003	
Median year of standards stock	-0.001	0.007		-0.006	0.006		-0.006	0.004	*	0.001	0.002	
Sector output (log)	-0.029	0.016	*	-0.011	0.013		-0.007	0.008		-0.005	0.005	
No of obs	5017			5017			5017			5017		
LR	769.26			747.62			644.58			250.45		
Pr (Chi2)	0.000		***	0.000			0.000			0.000		
Pseudo R2	0.117			0.121			0.136			0.087		

Note: * significant at 10% ** significant at 5% *** significant at 1%

TABLE A6
Strategy Delivery: Inputs

Logistic Regression

Dependent Variable	*Internal R&D*			*External R&D*			*Equipment*			*Computer*			*Software*		
	marginal probability	standard error	sig.	marginal probability	standard error	sig.	marginal probability	standard error	sig.	marginal probability	standard error	sig.	marginal probability	standard error	sig.
Variable															
Factor 1	0.199	0.015	***	0.055	0.008	***	0.102	0.012	***	0.062	0.013	***	0.097	0.014	***
Factor 2	0.093	0.015	***	0.039	0.008	***	0.127	0.012	***	0.114	0.013	***	0.123	0.014	***
Cluster 2 membership	0.136	0.041	***	0.054	0.029	*	0.000	0.034		0.036	0.035		0.015	0.036	
Cluster 3 membership	0.071	0.044		0.018	0.027		-0.038	0.036		-0.045	0.038		-0.065	0.038	*
R&D (log)	0.062	0.012	***	0.010	0.005	*	-0.021	0.008	**	0.046	0.010	***	0.021	0.011	**
Appropriability	-0.012	0.278		0.189	0.122		0.597	0.195	***	-0.219	0.238		-0.053	0.244	
Standards stock (log)	0.044	0.011	***	0.001	0.005		-0.004	0.008		0.027	0.010	***	0.017	0.010	*
Median year of standards stock	-0.014	0.008	*	0.000	0.004		-0.019	0.005	***	0.013	0.007	*	0.021	0.007	***
Sector output (log)	-0.113	0.018	***	-0.013	0.008		-0.032	0.013	**	0.015	0.015		0.009	0.015	
No of obs	5017			5004			5005			5007			5008		
LR	1452.370			336.870			767.930			272.700			338.720		
Pr (Chi2)	0.000		***	0.000		***	0.000		***	0.000		***	0.000		***
Pseudo R2	0.210			0.083			0.128			0.040			0.049		

	Licence			*Training*			*Design*			*Marketing*			*Cooperation*		
	marginal probability	standard error	sig.	marginal probability	standard error	sig.	marginal probability	standard error	sig.	marginal probability	standard error	sig.	marginal probability	standard error	sig.
Variable															
Factor 1	0.042	0.007	***	0.113	0.013	***	0.121	0.012	***	0.181	0.014	***	0.129	0.013	***
Factor 2	0.026	0.007	***	0.115	0.013	***	0.062	0.012	***	0.060	0.014	***	0.113	0.013	***
Cluster 2 membership	0.025	0.024		0.081	0.037	**	0.152	0.039	***	0.115	0.038	***	0.092	0.032	***
Cluster 3 membership	0.019	0.024		0.041	0.038		0.100	0.039	**	0.088	0.041	**	-0.006	0.036	
R&D (log)	0.000	0.005		0.029	0.009	***	0.024	0.009	***	0.020	0.011	*	0.015	0.011	
Appropriability	0.296	0.106	***	-0.267	0.218		0.107	0.200		0.108	0.249		0.492	0.254	*
Standards stock (log)	-0.002	0.005		0.025	0.009	***	0.038	0.008	***	0.008	0.010		0.007	0.010	
Median year of standards stock	0.005	0.003		0.011	0.006	*	0.007	0.006		-0.012	0.007	*	0.003	0.007	
Sector output (log)	0.010	0.007		-0.026	0.014	*	-0.054	0.013	***	0.016	0.016		0.006	0.016	
No of obs	5004			5007			5007			0	5007		5017		
LR	200.710			580.040			884.590			0.000			769.260		
Pr (Chi2)	-0.004		***	0.000		***	0.000		***	0.000		***	0.000		
Pseudo R2	0.062			0.091			0.144			0.000			0.117		

Note: * significant at 10% ** significant at 5% *** significant at 1%