Department for **Innovation, Universities** & **Skills**

How Innovative are UK firms?

Evidence from the 4th Community Innovation Survey (CIS4) on the Synergistic Effects of Innovations

Dr. Giuliana Battisti and Professor Paul Stoneman

DIUS Research Report 09 08

How Innovative are UK firms?

Evidence from the 4th Community Innovation Survey (CIS4) on the Synergistic Effects of Innovations

Dr. Giuliana Battisti

Aston Business School

and

Professor Paul Stoneman*

Warwick Business School

DIUS Research Report 09-08

May 2009

---

* With grateful thanks to our joint doctoral student Amid Mourany for his assistance with some of the statistical material

EXECUTIVE SUMMARY

This study uses the 4th Community Innovation Survey (CIS4) to explore the pattern of use of innovations in UK industry and to test for the existence of complementarities. Two innovation "factors" are isolated the most important including 'wide' innovative activities such as marketing, organizational, management and strategic innovations, the second set comprising more 'traditional' activities such as process, product and technological innovations.

Based upon the intensity of 'wide' and 'traditional' innovative activities three clusters of firms are identified each reflecting the intensity of use of the two sets of innovations. This showed that wider innovations and traditional innovations are complements and not substitutes for each other. In particular, a cluster was found whose intensity of use of the two sets of innovation was below average. This is also the largest cluster containing about 50% of the firms in the sample. A second cluster (containing about 23% of the establishments in the sample) was found with intermediate but above average use of the innovative activities. Finally a third cluster (containing about 19% of the establishment in the sample) was found, made up of highly intensive users seemingly capable of fully exploiting the synergistic effects generated by joint adoption of both traditional and wider innovations.

It is found that the within cluster size composition of firms is quite heterogeneous, the relative importance of large firms is highest in the third cluster; and the majority of small firms tend to populate the first cluster. We found no significant differences across the three clusters in the percentage of recently established establishments but the proportion of establishments that carry out in house R&D, the proportion of enterprises that carry out regular training, the proportion of employees with a degree either in science and engineering or other subjects, the percentage of firms that received public support and the proportion of firms that are part of a group (versus independent establishments) all increase as one moves from the first to the third cluster.

Within the production sector mining and quarrying, electricity, gas and water supply and construction are the least intensive innovators but overall the highest percentage of low intensity users are in two service sectors, retail trade and hotels and restaurants. By contrast, high technology sectors such as manufacturing of electrical and optical equipments, manufacturing of transport equipments are the sectors with the highest relative number of intensive users.

In terms of the impact of innovation upon firm performance the results clearly show that the largest share of those who reported 'high importance' (44.13%) are in cluster 3 while the largest proportion of the 'not relevant' (54.55%) can be found in the least innovative cluster (1) which is also the largest cluster.

Although the extent of product and process innovation remains largely unchanged since CIS3, the intensity of use of wider innovations has almost doubled. This confirms that wider innovative activities do play a key role in the innovative activity of firms and in the generation of the benefits from innovation

We conclude that these results give a more complete picture of innovative activity in the UK and that 'traditional' and 'wider' innovation activities should no longer be studied in isolation. A new integrated approach to the study of innovative activity should be taken in both theoretical and empirical research.

1. INTRODUCTION

Although it is acknowledged that there are problems in making such comparisons, most obviously concerning how productivity is measured, much past research has focussed on the productivity gap that exists **between** the UK and its major international competitors, including Germany, France and especially the US (O'Mahony and De Boer 2002). Also, although there are problems in how cleanly various sectors can be delineated and compared (Reynolds et al. 2005, Griffith et al. 2005), it is clear that a productivity gap of some substantial size exists across various sectors **within** the UK. Much of the research attempting to understand the sources of such productivity gaps (see for example McKinsey 1998, ESRC Seminar Series 2004[1]) has been undertaken at the macro level of analysis. However, increasing interest is now being paid to differences at the firm level, i.e. at a micro-level of analysis. It is to this micro literature that this research contributes.

One stream of research has increasingly emphasised that differences at the firm level may be a function of how companies are managed. This is in line with Porter and Ketels (2003) who, in their review of the state of the UK competitiveness, suggest that one explanation for the productivity gap concerns the use and the effectiveness of modern management practices by UK firms. The role of new work and management practices in the performance of a firm is also emphasised by, for example. Berman et al (1994, 1997), Cappelli and Neumark (2001), Bloom and Van Reenan (2006). Such studies show that (since the IT revolution at least) the simple adoption of technological innovations is no longer sufficient to gain competitiveness if they are not accompanied by a cluster of related innovations in production, organization, customer and supplier relationships and new product design. This is equivalent to stating that there are positive synergistic gains to be realised from simultaneous innovation on several fronts. The implication is often drawn that UK companies need to move away from cost minimizing strategies and instead add value to their products. However this often requires cognitive skills that not all firms possess (Black and Lynch 2004, Bresnahan et al 2002, Brynjolfsson et al 2002, Milgrom and Roberts 1990, 1995, Battisti et al 2005, etc.).

Although it is often argued that what is organisationally or managerially best for a firm may depend upon size, markets, objectives, ownership, environment, etc. at any moment in time for any given organization there may be an optimal organization form or set of management methods that if used by the organization will yield the greatest benefit (Birdi et al 2003). Following this line of argument Edwards, Battisti and Neely (2004) in a recent report to the DTI on ''how can UK firms be encouraged to create more value'' suggest that the strategic options potentially open to UK businesses embarking on new value adding activities are represented by:

- Increasing efficiency and effectiveness through the adoption of better practices;
- Innovating to produce products and or services that can generate more revenue - either through higher prices or larger volumes;
- Fundamentally changing position in the supply chain and moving to a position where the products and services that are being delivered inherently generate more value

[1] See also Battisti and Iona (2006b) for a review of the literature on the productivity gap and the role of management practices in closing such a gap.

The main policy implication is that these three strategies should be explicitly recognised and incorporated into any strategy for innovation. However, it is only from the understanding of the complexity and the functioning of firms' internal organization, the adoption of management practices, and more generally, the extent of product and process innovation, that the dynamic of value creation can be understood.

In fact, currently our knowledge of these strategic, organisational or managerial issues is quite limited, let alone their relation to more traditionally considered innovative activity. At least partly this is due to (large scale) data availability, in that innovation that does not concern process, product and technological innovations has been largely neglected in the (at least empirical) literature. In essence a broad definition of innovation must be adopted[2]. In this paper, we do that by means of the information contained in the CIS4 dataset, and adopt a definition of innovative activity based upon the adoption of a range of innovations, including: management practices, new organizations, new marketing concepts, new corporate strategies as well as the more traditionally measured introduction of process, product and technological innovations[3].

In the following sections, by the means of statistical tools of analysis, the existence of complementarities among a range of innovations is modelled leading to the identification of clusters of firms based upon the intensity of their innovative activity. Special attention is paid to the characteristics of the firms within each cluster and whether significant differences exist with respect to the types of innovations introduced. Once the existence of clusters of innovative activities is established we assess the impact of the innovative activities upon firm performance with special emphasis upon persistence in innovation.

The paper is structured as follows: Section 2 introduces the dataset and the key variables of interest. Section 3 tests for the significance of synergistic gains. Section 4 maps the intensity and clustering of the use of 7 innovative practices across the sample of firms. Section 5 assesses use of innovations and firm characteristics, section 6 explores the impact of innovative activities upon firm performance, section 7 looks at persistence in innovation and section 8 concludes.

[2] This is in line with the 3rd edition of the Oslo Manual adopted in the CIS survey, that as reported in the call for proposals 'offers a wider definition of the innovation concept to encompass organisational and marketing forms, in addition to the traditional modes of product and process innovation'.

[3] For earlier related work see J Wengel and P Stonemanet al " *Surveying Organisational Innovation on a European Level - Challenges and Options,* a Report to the CIS, DG XIII - C of the European Commmssion, April 2000.

2. THE CIS4 DATASET AND MEASURES OF INNOVATIVE ACTIVITY

The detail upon the questionnaire, the data collection process, sampling etc in the UK CIS4 can be found elsewhere (www.dti.gov.uk/innovation/innovation-statistics/cis/cis4) and is not repeated here. The salient points for our purpose are that the dataset contains information on a wide range of innovative activities carried out by firms. In particular it contains information on whether between 2002-2004 the sample companies had introduced: new product innovations (PRODINOV); new process innovations (PROCINOV); and any technological innovation such as new machinery, equipment and computer hardware or software to produce new or significantly improved good, services, production processes or delivery methods (MACHINE). Further to these traditional indicators of innovative activities, CIS4 also contains information on the introduction of wider concepts of innovations defined as 'new or significantly amended forms of organization, business structures or practices, aimed at step changes in internal efficiency of effectiveness or in approaching markets and customers'. In particular, question 23 contains information on whether the enterprises have made major changes in the areas of business structure and practices during the three year period 2002-2004 concerning: the implementation of new or significantly changed corporate strategy (STRATEGY); Implementation of advanced manufacturing techniques (MANAGEMENT); implementation of major changes to the organizational structure (ORGANIZATION); and implementation of marketing concepts or strategies (MARKETING).

Out of the 16383 enterprises who responded to the CIS4 questionnaire on average about 20% have adopted at least one of the innovations, the exception being MACHINE, which has been adopted by about half of the sample. Table 1 reports the variable definitions and the percentage of adopting firms in the sample.

Table 1 - Definition of Innovation variables and sample adoption (%)

Innovation Variable label	Definition	Adopting firms
PROCINOV	Whether a product innovation (new to the enterprise or to the market or a significantly improved good or service) has been introduced on the market between 2002-2004: (see Q7-Q8).	20%
PRODINOV	Whether a process innovation (new to the enterprise or to the market that significantly improved methods for the production or supply of goods and services) has been introduced between 2002-2004: (see Q11).	29%
MACHINE	Whether advanced machinery, equipment and computer hardware or software to produce new or significantly improved goods, services, production processes, or delivery methods has been acquired between 2002-2004: (see Q13).	47%
STRATEGY	Whether a new or significantly changed corporate strategy has been implemented between 2002-2004 (see Q23.10).	19.9%
MANAGEMENT	Whether advanced management techniques e.g. knowledge management systems, Investors in People etc has been implemented between 2002-2004 (see Q23.20).	17.6%
ORGANIZATION	Whether major changes to the organisational structure, e.g. introduction of cross-functional teams, outsourcing of major business functions have been implemented between between 2002-2004 (see Q23.30).	22.6%
MARKETING	Whether changes in marketing concepts or strategies, e.g. packaging or presentational changes to a product to target new markets, new support services to open up new markets etc. have been implemented between 2002-2004 (see Q23.40).	23%

3. COMPLEMENTARITIES IN INNOVATIVE ACTIVITIES

Recent theoretical and empirical research has increasingly recognized that to look at the adoption of stand alone innovations may be misleading since firms often tend to adopt clusters of innovations rather than individual practices and innovations in isolation. The supposition is that joint adoption can significantly improve productivity, increase quality and often result in better corporate financial performance relative to isolated instances of innovation. Milgrom and Roberts (1995), indeed, explicitly claim that bundling more innovative practices together is not an accident. Rather, it is the result of the adoption by profit-maximizing firms of a coherent strategy that exploits complementarities. Similarly, Battisti et al. (2005) within a causality framework find important complementarities generated by the existence of extra profit gains from joint adoption rather than from individual adoption of work practices. Complementary innovations are essentially innovations where the overall net gain from joint adoption is higher than the sum of the net gain from individual adoption (see for example Ichniowski et al. 1997, Whittington et al. 1999, Battisti and Iona 2006.a for examples of super-additivity and clusters of innovations, or the formalised models of Battisti et al 2005 or Stoneman 2004 for substitute and complementary technologies, etc.).

In Table 2, using the CIS4 data summarised in Table 1 we report the Kendall's tau-b correlation coefficient for the 7 innovation variables in order to indicate the extent to which the sample firms between 2002 and 2004 undertook isolated innovation practices or instead undertook simultaneous innovation practices. The Kendall's tau-b correlation coefficient is a non-parametric measure of association based on the number of concordances and discordances in paired observations. For all the variables the pair wise degree of association is significantly different from zero showing that the decision to adopt one practice is not independent of the decision to adopt another practice and that the adoption of all practices is correlated with the adoption of all others. However, the degree of association differs in intensity and varies from practice to practice. This reflects the fact that some practices may be more influential than others.

Table 2 - Correlation Matrix Kendall's tau_b correlation coefficient (N=15657)

	Prodinov	**Procinov**	**Machinery**	**Strategy**	**Management**	**Organiz**	**Marketing**
Prodinov	1.000						
Procinov	0.429	1.000					
Machinery	0.319	0.360	1.000				
Strategy	0.275	0.253	0.198	1.000			
Management	0.214	0.238	0.220	0.407	1.000		
Organiz	0.275	0.255	0.204	0.543	0.412	1.000	
Marketing	0.338	0.293	0.252	0.448	0.381	0.445	1.000

The existence of significantly positive pair wise correlations between the adoption of different innovative practices is not necessarily proof of complementarities. The correlations may be the result of lurking factors and therefore present spurious correlation. To test the robustness of the pair wise correlations and to control for the presence of lurking factors, we follow Arora and Garbardella (1995) and Arora (1990). They argue that a better test involves use of the elements of the conditional covariance matrix, which models the probability of adopting any one innovative practice after controlling for the impact of a number of firm characteristics and other industry specific factors.

Table 3 - Control variables, conditional adoption probabilities

Label	Definition
SIZE	Number of employees
GROUP	Whether part of a group (1) or independent establishment (0)
INTERNAT	Whether the market is international (1=yes; 0 = no)
AGE	Whether established after 2000 (1=yes; 0=no)
R&D	Whether the enterprise engages in R&D activities (1=yes; 0=no)
SCDEGREE	Percentage of the enterprise's employees educated to degree level or above in Science and Engineering subjects
OTHDEGREE	Percentage of the enterprise's employees educated to degree level or above in other subjects.
SUPPORTPU	Whether received any public financial support (1=yes; 0=no)
SICj	Industry to which the establishment belongs; j=1 to 14,wide SIC92 classification.

The control variables that we have included have been partly dictated by the economic analysis of technology diffusion and partly by data availability. They are the size of the firm (SIZE), whether the firm belongs to a group (GROUP), whether the market for its final product is international (INTERNAT), whether the firm was established after 2000 (AGE), whether the firm engages in R&D (R&D), the percentage of employees with a degree in Science or Other degree (SCdegree and OTHdegree) and whether the company received any public financial support (SUPPORTPU). We also include a series of 12 industry dummy variables to reflect different industry (wider subgroup) conditions, markets, and types of innovations and payoffs to firms in different industries. The industrial classification follows the SIC 92 as defined in Appendix1. A summary of the variables definitions is reported in Table 3.

Table 4 - Control factors and the probability of adoption, probit estimates

	PROCINOV	PRODINOV	MACHINERY	STRATEGY	MANAGEMENT	ORGANIZ	MARKETING
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
ONE	**-1.274**	**-0.972**	**-0.630**	**-1.329**	**-1.271**	**-1.311**	**-1.244**
GROUP	**0.208**	**0.236**	**0.042***	**0.370**	**0.300**	**0.491**	**0.282**
INTERNAT	-0.027	0.005	**0.148**	0.060	0.019	0.060	**0.178**
AGE2000	-0.001	**0.073**	-0.019	**0.213**	-0.040	**0.086**	**0.065**
RD	**0.807**	**1.135**	**0.953**	**0.604**	**0.568**	**0.624**	**0.813**
SCDEGREE	0.001	**0.001**	-0.001	**0.001**	0.000	**0.001**	0.001
OTHDEGRE	**0.001**	**0.002**	**0.001***	**0.002**	**0.001**	**0.002**	**0.002**
SUPPORTP	**0.522**	**0.616**	**0.396**	**0.387**	**0.384**	**0.310**	**0.404**
EMPLOYME	**0.000**	**0.000**	0.000	**0.000**	**0.000**	**0.000**	**0.000**
D1	-0.084	**-0.773**	0.020	-0.042	-0.150	-0.102	**-0.465**
D2	**0.170**	**-0.110**	**0.323**	**-0.151**	**-0.235**	**-0.133**	**-0.122**
D3	0.077	-0.054	**0.228**	**-0.160**	**-0.153**	-0.092	**-0.321**
D4	0.060	**0.192**	**0.154**	-0.085	**-0.219**	0.064	**-0.227**
D5	0.056	-0.016	**0.224**	-0.071	-0.088	0.098	**-0.453**
D6	0.010	-0.017	**0.227**	**-0.185**	**-0.284**	-0.126	**-0.234**
D8	**-0.367**	**-0.469**	-0.031	**-0.163**	0.082	-0.105	**-0.323**
D10	**-0.272**	**-0.417**	**-0.231**	**-0.272**	**-0.328**	**-0.317**	**-0.276**
D11	**-0.406**	**-0.523**	**-0.287**	**-0.355**	**-0.178**	**-0.337**	**-0.355**
D12	-0.078	**-0.186**	**0.190**	-0.121	**-0.124**	-0.092	**-0.219**
D13	**0.234**	-0.084	**0.156**	**0.236**	0.028	0.261	0.072
D14	**0.184**	**-0.109**	0.013	0.075	0.056	0.122	-0.087

*coefficients significant at 5% in bold

Using a probit model we relate the probability of adoption of each of the innovative practices against the control variables listed above. The results are presented in Table 4. Without going in to great detail on these estimates, suffice it to say that they are largely in line with our prior expectations.

Pursuing our aim of modeling the probability of adopting any one innovative practice after controlling for the impact of a number of firm characteristics and other industry specific factors, we now test for the significance and the positiveness of the off diagonal elements of the covariance matrix of the standardized residuals of the probit specifications. The results of the correlation matrix are reported in Table 5. The results clearly indicate that there exist important and significant correlations among the adoption of the set of innovations although we note (for later purposes) that the correlation between the adoption of new machinery and new strategies has turned out to be of borderline significance.

Table 5 - Non-parametric Kendall's tau_b correlations of the residuals[a]

	R_Process	R_Product	R_Machinery	R_Strategy	R_Management	R_Organizat	R_Marketing
R_Process	1.000	0.161	0.131	0.212	0.178	0.192	0.253
R_Product	0.161	1.000	0.297	0.070	0.025	0.106	0.140
R_Machinery	0.131	0.297	1.000	*0.015**	0.027	0.055	0.070
R_Strategy	0.212	0.070	0.015	1.000	0.377	0.489	0.392
R_Management	0.178	0.025	0.027	0.377	1.000	0.329	0.296
R_Organizat	0.192	0.106	0.055	0.489	0.329	1.000	0.422
R_Marketing	0.253	0.140	0.070	0.392	0.296	0.422	1.000

* Correlation is NOT significant at the 0.01 level (p=0.0067).

a Listwise N = 15082

Arora and Garbardella (1995) and Arora (1990) argue that one may define innovative activities as complementary (exhibiting synergies) if the adoption of one raises the marginal payoff of others[4] (see also Whittington et al. 1999, Battisti et al 2005 and 2006 etc). They also show that such marginal payoff effects can be captured by the conditional covariance between the adoption of any two innovations A and B being positive. In other words the partial (conditional) covariance between any pair of innovations must be positive for complementarities to exist. The results in Table 5 (except between the adoption of new machinery and new strategies) give significant support to the view that there are significant complementarity effects from the joint use of innovations.

Having established the existence of joint use and potential complementarities we proceed in the next section to explore the patterns of use in greater detail, by modelling the extent of joint adoption and the way practices are combined and used at firm level.

[4] This is equivalent to saying that the second order cross derivative between innovation A and innovation B of the expected gain g, V= $^{2}g/$ A B, is positive - see Arora and Gambardella 1991 and Arora (1990) for more details.

4. THE INTENSITY AND CLUSTERING OF INNOVATIVE ACTIVITY

In order to identify the underlying pattern of intensity of use of different innovation practices by the sample of UK firms in 2004, without making any presumption as to what is the "best" combination, in this section we just let the data inform on the variability and the intensity of use of the different practices. We do so by performing iterated principal factor analysis (IPFA) based upon the decomposition of the tetrachoric correlation matrix of the pair wise adoption decision for the firms in the CIS4 sample (see above).

IPFA models the synergies amongst the innovations adopted and linearly transforms them to obtain a smaller set of variables uncorrelated with (orthogonal to) each other and defined so that the first factors are the vectors of coefficients (loadings) of the linear combination that explain the largest proportion of variance. In other terms, IPFA allows one to summarize the heterogeneity of use of the set of the 7 innovations via a reduced number of latent factors capable of picking up the underlying pattern of use that can explain the largest proportion of variability of the joint adoptions. This enables one to identify the innovative practices that play the major roles in the overall innovative activities of the firm

In Table 6 we report the tetrachoric correlation matrix for binary variables which confirms our findings above that important synergistic effects exists in several aspects of the innovative activities of the firm. In particular, the highest correlation has been found between process and product innovations, and among new strategy, management, organization and marketing practices.

Table 6 - Tetrachoric correlations (obs = 15657)

	prodinov	procinov	machinery	strategy	managm	organiz	marketing
prodinov	1.0000						
procinov	0.6643	1.0000					
machinery	0.5033	0.6116	1.0000				
strategy	0.4617	0.4378	0.3497	1.0000			
management	0.3773	0.4212	0.4000	0.6503	1.0000		
organiz	0.4540	0.4359	0.3500	0.7864	0.6547	1.0000	
marketing|	0.5412	0.4896	0.4266	0.6886	0.6174	0.6792	1.0000

Note. All coefficients are significant at 5%.

In Table 7 we report the rotated[5] factors loadings and their uniqueness. While the former are the coefficients of the linear combination of the original variables that decreasingly explain the largest part of the variability; the latter measure the proportion of variance of the variable that is not accounted for by all of the factors taken together[6]. The first factor (Factor 1) accounts for 83.5% (57% if rotated) of the total variability in firms' innovative activity and it is driven by the extent of use of strategy, management, organizational and marketing

[5] The extraction of principal components amounts to a *variance maximizing (varimax) rotation* of the original variable space. The rotated factor loadings, by stretching the loadings to their extremes (+1 or -1) improve the interpretative capability of the factors, without changing their nature or that of the model.

[6] A very high uniqueness can indicate that a variable may not belong with any of the factors. Uniqueness is 1-communality where communality reflects the common variance in the data structure, i.e. 56.8% of the variance associated with PRODINOV is common, or shared variance.

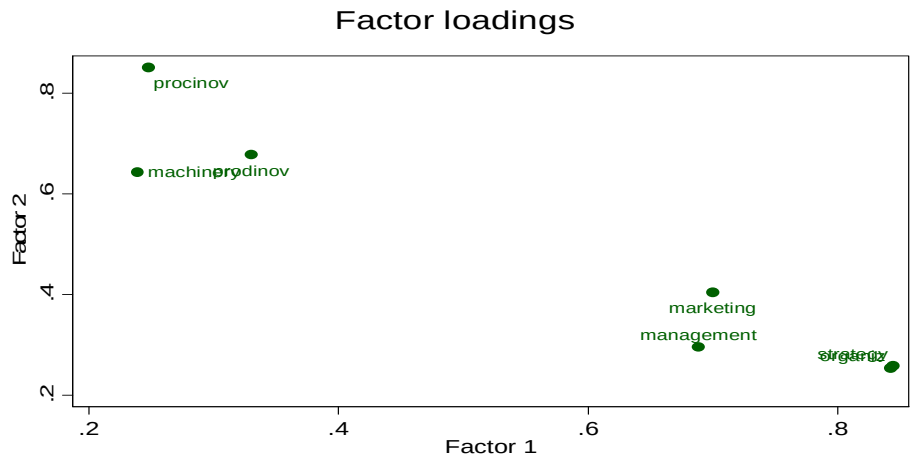
innovations. Following the definition adopted by the CIS4 survey, we label these practices 'wider innovations' as they '…*investigate new or significantly amended forms of organization, business structures or practices, aimed at step changes in internal efficiency of effectiveness or in approaching markets and customers*..' (see CIS4 questionnaire).

The second factor (Factor 2) in Table 7 explains 16.5% (43% if rotated) of the remaining variability in the heterogeneity of use of innovative activities by the firms in the sample and it is driven by what we define 'traditional' innovations such as product, process and technological innovations. This can be better seen in Figure 1 that reports on the two axes the rotated factor loadings. On the x-bar the principal factor shows the importance of 'wider' innovations (strategy, management, organization and marketing), while on the y-axis the second factor shows the importance of 'traditional' innovations (process, product and technological innovations).

Table 7 - Rotated Factor Loadings

Variable	Factor1	Factor2	Uniqueness
prodinov	0.3300	**0.6778**	0.4316
procinov	0.2477	**0.8514**	0.2137
machinery	0.2390	**0.6439**	0.5283
strategy	**0.8442**	0.2577	0.2209
management	**0.6884**	0.2950	0.4391
organiz	**0.8422**	0.2539	0.2262
marketing	**0.6997**	0.4044	0.3470
%var	83.5% (57% R)	16.5% (43% R)	

Figure 1 - Rotated factor loadings



Rotation: orthogonal varimax
Method: iterated principal factors

For all the variables used in the IPFA analysis the uniqueness statistic indicates that most of their heterogeneity of use is largely related to the extent of use of the other variables. Interestingly, technological innovations per se (MACHINERY) are the innovations that have the least shared variance and it is the most adopted (in fact about 47% of the firms in the sample employ this innovation). This could indicate (i) that most firms do engage in technological innovations but, reinforcing the argument of Edwards et al. 2003, the innovations are more oriented towards cost minimizing strategies rather than value added strategies and (ii) as MACHINERY incorporates software and PCs it may be that IT has become so widespread that it no longer yields a competitive advantage to adopters. The latter is consistent with the observation that MACHINERY is the dominating factor load in the third factor extracted by the IPFA analysis but the percentage of variance explained is just 6.7%.

The IPFA analysis in summary suggest that, although the innovation literature has been mainly concerned with 'traditional' innovations, 'wider innovations play a predominant role in the innovative activity of UK firms. As such both research and policy agendas may need considerable reconsideration.

Having identified the two factors, we have carried out a two-step cluster analysis over the projection of the firms standardized factor scores (the latter being the summary information of the intensity of use of each factor) in order to identify the existence of clusters of firms based upon the intensity of use of the 7 innovations. This has resulted in 3 clusters being identified including 9317 (cluster 1), 3881 (cluster 2), 3185 (cluster 3) enterprises respectively. For this model, the Kaiser-Meyer-Olkin measure of overall sampling adequacy is 0.8652. In Figure 2 we report the 95% confidence intervals for the average intensity of use (i.e. average standardized factor score) of Factor 1 calculated for each of the three clusters and similarly for Factor 2.

Figure 2 - Confidence intervals for the mean of Factor 1 (on the left) and Factor 2 (on the right)

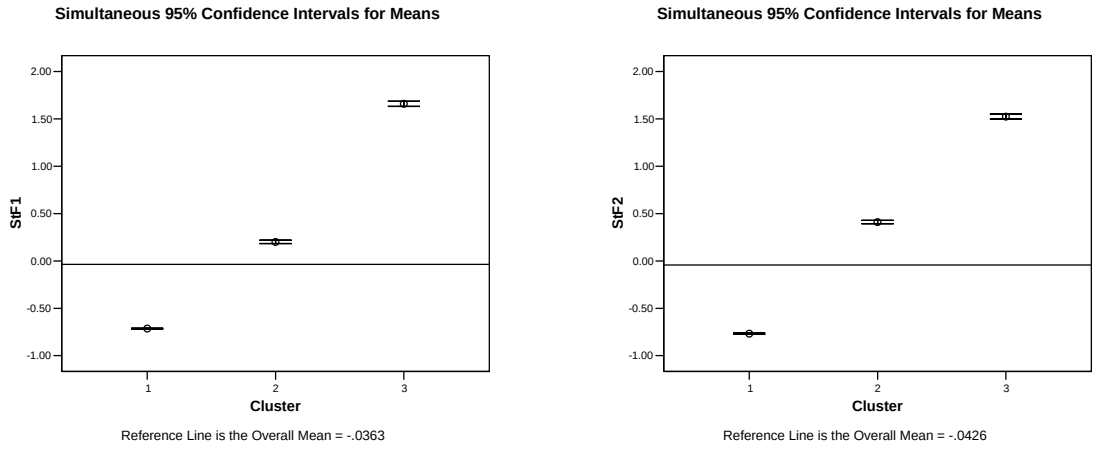


Figure 2 essentially reflects the intensity of adoption of wider innovations in each of the three clusters. Cluster 1 uses 'wide' innovations at levels below the sample average (average standardised factor score) represented by the straight horizontal line. The other two clusters are made of firms that use 'wide' innovation activities progressively more intensively. The same can be said for the second factor illustrating the intensity of use of the more traditional innovations such as process, product and technological innovations (see Figure 2b.). Jointly, the two graphs allow one to identify three groups of firms. The low intensity of use innovators (cluster 1), the intermediate innovators (cluster 2) and highly innovative users (cluster 3).

Moreover, while cluster 1 is the largest sample, cluster 3 is the smallest one. To the extent that the CIS4 is representative of the UK population, this suggests that about 19.4% of the UK firms operate well above average in terms of innovative activity while 56.9% perform below the average.

Interestingly, across the clusters we find that Factor 1 innovation is positively associated with Factor 2 innovation, suggesting that wider innovations and traditional innovations do not represent alternatives or competing innovation strategies. They must instead be considered as complements rather than substitutes and thus exhibiting synergistic effects.

5. INTENSITY OF USE AND FIRM CHARACTERISTICS

To explore the characteristics of firms in each of the three clusters Table 8 reports the percentage of the firms within each cluster that have introduced each of the 7 innovations. As predicted by the factor analysis the intensity of use of the practices is highest in cluster 3 where a majority of the firms have adopted each of the 7 innovations. Cluster 1 contains the least 'innovative' firms. Within this cluster less than 2% of the firms report having carried out 'wide' innovative activities, about 22% have introduced technological innovations and 6% have developed new products but (not shown) only 2.3% of those products (against 42% in cluster 3) were new to the market rather than just new to the firm.

Interestingly, the extent of technological innovation as measured by MACHINE is comparatively high in each of the three clusters, although its intensity is less than proportional to the extent of overall firm innovativeness. This may confirm that technological innovations can be more easily be introduced and assimilated than innovations such as organizational innovations or a product new to the market, which require flexibility and cognitive skills that not all firms might possess (see Bresnahan 2002, Battisti et al 2005, Colombo and Delmastro 2002, etc).

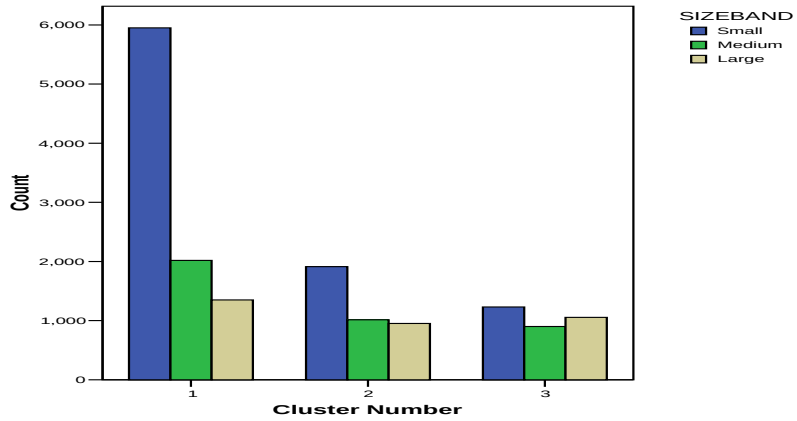
Table 8 - Within cluster percentage of firms who report having introduced the innovations

	Managem	Strategy	Organiz	Marketing	Prodinov	Procinov	Machinery
Cluster 1	1.5	1.2	2.0	1.6	6.0	1.3	22.3
Cluster 2	18.7	20.7	25.8	27.8	48.2	32.4	71.5
Cluster 3	59.2	69.0	73.5	74.9	76.1	62.9	84.1

In order to highlight the characteristics of the firms in the three clusters we report some descriptive statistics of the firms in each cluster in Table 9. Firm size has a long history as a key factor in innovation diffusion studies (see for example Mansfield (1968), Hannan and MacDowell (1984), Karshenas and Stoneman (1993), Saloner and Shephard (1995), Colombo and Mosconi (1995), and Astebro (2002)). Size might pick up a number of other firm characteristics such as efficiency, management abilities, organizational structure, etc (see Astebro, 1995) and any scale economies that there might be associated with the introduction of such innovations.

The first column of Table 9 reports the size of the firm, measured by the number of employees in 2004. Interestingly, the extent of firm innovativeness seems to increase with firm size, with cluster 1 firms being mostly small (trimmed mean = 76.84; median =27), cluster 2 being mainly medium sized firms (trimmed mean = 140.93; median = 52) and cluster 3 being medium to large firms (trimmed mean = 219.30, median =81.5). However, the standard deviations are very large suggesting that the averages can be highly misrepresentative. In order to visualize the within cluster distribution of firm size in Figure 3 we group the firms in each cluster into 3 classes: small (10-49 employees), medium (50-249) and large (250 or more). Figure 3 shows that: cluster size compositions are quite heterogeneous; the relative importance of large firms is highest in the third cluster; and the majority of small firms tend to populate the first cluster.

Figure 3 - Intra-cluster firm size composition



The age of the establishment is also reprted according to the view that older plants generally have more experience that allows them to assess costs and benefits of any changes better that younger plants (see for example Noteboom 1993). Nevertheless, older plants might also be less flexible in introducing innovations due to the nature and complexity of their organizational structure (see Little and Triest 2996, Battisti 2000, Battisti et al 2006) or the resistance of employees to the introduction of innovations (see Ichniowski et al. 1995). In the CIS4 questionnaire there is a question on whether the company was established after 1ST of January 2000. We use it as a proxy for young and old establishments but we find no significant differences across the three clusters in the percentage of recently established enterprises[7].

[7]On the grounds that young firms are innovative in all dimensions and this might bias our results we have checked their robustness by re-running our analysis excluding those firms established after 2000 (2788 observations). The tetrachoric correlations do not substantially change.

Table 9 - Firms characteristics: descriptive statistics

	Size (employees)	Age (whether est. after 2000)	R&D	Training	% with science degree	% with other degree	Part of a group	Public financial support	Internat market for its product	Service sector
CLUSTER 1										
Mean	**168.75***	**0.15**	**0.12**	**0.21**	**2.88***	**4.93***	**0.26**	**0.04**	**0.98**	**0.62**
5% Trimmed mean	76.84	0.11	0.08	0.18	0.88	2.11	0.24	0	1	0.63
Median	27	0	0	0	0	0	0	0	1	1
St. dev.	756.15	0.36	0.33	0.41	11.03	14.60	0.44	0.19	0.13	0.5
Min	9	0	0	0	0	0	0	0	0	0
Max	32655	1	1	1	100	100	1	1	1	1
CLUSTER 2										
Mean	**304.39***	**0.14**	**0.46**	**0.58**	**7.34***	**8.90***	**0.41**	**0.14**	**0.98**	**0.55**
5% Trimmed mean	140.93	0.10	0.46	0.59	4.18	5.82	0.40	0.10	1	0.56
Median	52	0	0	1	0	2	0	0	1	1
St. dev.	1281.23	0.35	0.50	0.49	17.06	17.78	0.49	0.35	0.15	0.50
Min	10	0	0	0	0	0	0	0	0	0
Max	48387	1	1	1	100	100	1	1	1	1
CLUSTER 3										
Mean	**470.68***	**0.16**	**0.68**	**0.76**	**11.00***	**11.46***	**0.53**	**0.25**	**0.97**	**0.55**
5% Trimmed mean	219.30	0.12	0.70	0.79	7.71	8.28	0.53	0.22	1	0.56
Median	81.5	0	1	1	2	5	1	0	1	1
St. dev.	2148.33	0.37	0.47	0.43	20.52	19.34	0.50	0.43	0.17	0.50
Min	10	0	0	0	0	0	0	0	0	0
Max	60498	1	1	1	100	100	1	1	1	1

We also found that the proportion of establishments that carry out in house R&D[8] is highest in cluster 3 and lowest in cluster 1 reflecting the Schumpeterian hypothesis that formalised R&D exerts a positive impact upon the use of an innovation. This is also in line with the view of Cohen and Levinthal (1989) who illustrate that firms which spend upon R&D are more easily able to assimilate innovations.

Whether firms carry out regular training increases progressively from cluster 1 to 3. The proportion of employees with a degree in science and engineering subjects seem to be slightly lower than the proportion with other degrees, although both increase as one moves from clusters 1 to 2 to 3 confirming the importance of the link between innovation and skills emphasised by, among the others, Caroli and Van Reenan, (2001), Bresnahan et. al (2002).

The percentage of firms that received public support increases with the extent of innovative activity carried out by the firm, reaching a peak of 25% in the highly innovative group (cluster 3). The proportion of firms that are part of a group (versus independent establishments) is higher in the cluster of high innovators than in the other clusters. No significant differences across clusters has been found with respect to whether the market for the firm final product is international or whether the company belongs to the service rather than the production sector.

[8] One might argue that R&D should be included among the 7 innovations under scrutiny. We decided not to go down that route as we wanted to concentrate on innovation outputs and not on innovation inputs.

In Table 9 we report the distribution of firms across industrial sectors (SIC92 classification - see appendix) by clusters. We observe that in every sector Cluster 1 contains the largest number of firms suggesting that the distribution of firm innovativeness is skewed to the right. Secondly, firms operating in the service sector are no more intensive as innovation users (i.e. belong to Cluster 3) than firms in other sectors. Thirdly, within the production sector, perhaps unsurprisingly mining and quarrying, electricity, gas and water supply and construction are the least intensive innovators. By contrast, high technology sectors such as manufacturing of electrical and optical equipments, manufacturing of transport equipments (followed by manufacturing of fuels, chemicals, plastic metals & minerals) are the sectors with the highest relative number of intensive users.

Surprisingly the two sectors with the highest percentage of low intensity users are in services. They are retail trade and hotels and restaurants. These are two sectors previously noted in the literature as exhibiting a particularly wide productivity gap relative to other sectors (see for example Griffith et al. 2003).

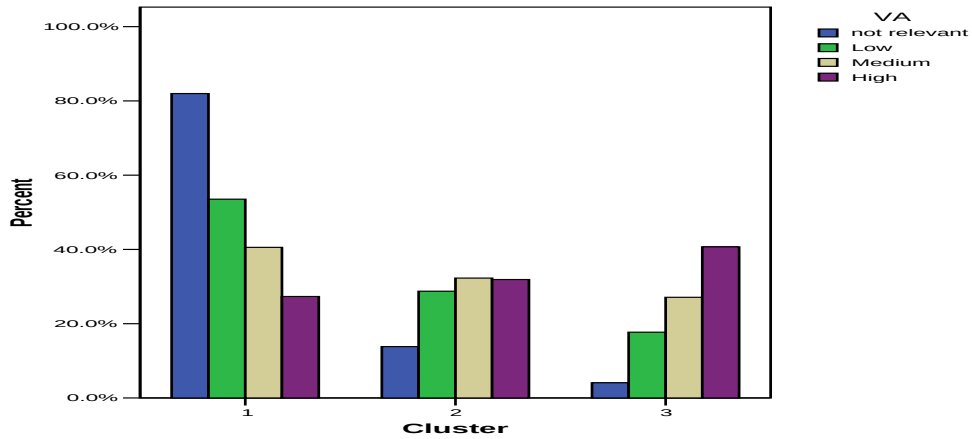
Table 9 - Distribution of firms across sectors by clusters

SIC Classification	Definition	Cluster 1	Cluster 2	Cluster 3	*Total (count)*
Production					
10-14	Mining and quarrying	**60.9**	24.4	14.7	*(197)*
15-22	Mfr of food, clothing, wood, paper, publish & print	48.6	28.8	22.6	*(1432)*
23-29	Mfr of fuels, chemicals, plastic metals & minerals	48.6	27.7	23.7	*(1897*
30-33	Mfr of electrical and optical equipments	34.8	31.7	**33.5**	*(663)*
34-35	Mfr of transport equipments	44.5	27.4	**28.1**	*(402)*
36-37	Mfr not elsewhere classfied	47.4	30.3	22.3	*(515)*
40-41	Electricity, gas & water supply	**68.6**	20.0	11.4	*(35)*
45	Construction	**72.9**	17.0	10.1	*(1603)*
Services					
50-51	Wholesale Trade (including cars & bikes)	59.6	23.7	16.7	*(1341)*
52	Retail Trade (excluding cars & bikes)	**73.6**	17.4	9.1	*(1543)*
55	Hotels & restaurants	**74.9**	15.7	9.5	*(983)*
60-64	Transport, storge & communication	63.3	21.2	15.5	*(1386)*
65-67	Financial intermediation	44.6	24.4	**31.0**	*(668)*
70-74	Real estate, renting & business activities	50.8	25.3	23.9	*(3718)*
Total		*56.9*	*23.7*	*19.4*	*(16383)*

6. INTENSITY OF INNOVATION AND FIRM PERFORMANCE

In order to investigate differences in the performance of the companies in the three clusters we use performance indicators available from the responses to the CIS4 questionnaire (although they are mostly based upon a view of innovation as product innovation). An obvious starter for measuring impact on performance is the impact of innovation upon firm value added. Unfortunately, we do not have direct measures of the value added due to each or any of the innovative activities investigated in the previous section[9]. However, CIS4 contains a question (Q1290) on the establishment's own estimate of the effect of the introduction of product and processes in increasing value added. The responses are reported in Table 10 and diagrammatically in Figure 4.

Figure 4 - Inter cluster distribution of the degree of importance of product and process innovation in generating VA



The responses to Q1290 clearly show that the largest share of those who reported 'high importance' (44.13%) are in cluster 3 while the largest proportion of the 'not relevant' (54.55%) can be found in the least innovative cluster (1) which is also the largest cluster.

Table 10 - Degree of importance of product and process innovation in generating Value Added: within cluster composition (column %).

	Cluster 1	Cluster 2	Cluster 3
Not relevant	**54.55**	19.75	7.09
Low	11.49	13.23	9.84
Médium	22.50	**38.38**	**38.94**
High	11.46	**28.64**	**44.13**
Total	100.00	100.00	100.00
Total (count)	***8178***	***3817***	***3159***

[9]Moreover, even if we did the nature of the dataset is such that it would be difficult to establish the direction of the casual relations between adoption timing and payoff from adoption.

Further to question Q1290, the CIS4 questionnaire also contains a question (Q8) on the firm's estimated percentage of turnover in 2004 due to different levels of product innovation introduced between 2002-2004. The heterogeneity of the responses is such that averages would not be representative of the intensity of the responses. We therefore use the distribution of the responses across the different categories as a proxy for the within cluster intensity of adoption. In table 11 we report the inter cluster distribution of firms that indicated their turnover was somehow affected by the intensity of product innovation. For all types of innovation introduced the majority of the innovative firms are in cluster 3 and only few of them (10% or fewer) are in Cluster 1. However, only 4629 respondents, about ¼ of the firms in the sample replied to this question.

Table 11 - Inter cluster distribution of the % of firms who ticked each of the four options (row %)

	Cluster			
	1	**2**	**3**	**Total (firm count)**
Turnover affected by the introduction of products new to market	9.1	35.4	55.5	100 (2359)
Turnover affected by the introduction of products new to the enterprise	9.6	37.8	52.6	100 (3182)
Turnover affected by the introduction of significantly improved products	8.6	36.7	54.7	100 (2916)
Turnover affected by products unchanged or marginally modified	10.4	39.0	50.6	100 (4189)

We have undertaken similar analysis on responses detailing firms views as to the impact of innovation upon turnover. These we do not report in detail but the results are similar to the above. Innovation gets to be more important as a determinant as one moves from cluster 1 to cluster 2 to cluster 3 firms.

7. INNOVATION PERSISTENCY: EVIDENCE FROM CIS4 AND CIS3

In this section we explore whether firms that are innovative are also continuously innovative. This has two purposes. The first is that we may then explore whether just as performance may result from clusters of innovation rather than isolated individual innovations so it may be the case that, intertemporally, continuous innovation is required to improve performance rather than isolated instances of innovation. Secondly our data indicates whether firms introduced particular innovations in the 2002-2004 period and does not distinguish within the non innovator group from those who introduced innovations at other times from those who are non innovators which the persitency analysis my overcome.

We compare the extent of innovative activity reported by the cohort of firms in the CIS4 (16383 establishments) and the CIS3 (8172 establishments). While CIS4 covers innovative activity carried out between 2002 and 2004, the CIS3 covers innovative activity carried out between 1998 and 2000. Due to the nature of the sample design of the two surveys there are only 959 establishments for which we have information in both surveys.[10]

In the first two columns of Table 12 we report the proportion of establishments that have introduced each of the studied innovation in the two time periods (2002-2004 and 1998-2000). This provides us with an overview of the inter-temporal dimension of the intensity of use of each of the 7 innovations under scrutiny. Although the extent of product and process innovation remains significantly unchanged in the two time periods (Test for equality of proportions: $z_{PRODINOV}$ = -4.1394 p=0.00 and $z_{PROCINOV}$ = -2.1446 p=.016), the intensity of use of wider innovations has almost doubled. Also the introduction of technological innovations has increased dramatically but this is likely to be due to the new definition adopted in the CIS4 which has been changed to include software and a wider definition of supporting innovative activities which were not previously included in the CIS3 version of the questionnaire[11].

[10] We have tried to build a panel merging the information in the CIS2, CIS3 and CIS4. Unfortunately this reduces the sample to 101 establishments making any statistical analysis totally unrepresentative of the UK establishments population.

[11] In the CIS4 the relevant question is Question 13.30 on whether in the three year period 2002-2004 the enterprise engaged in the following activity: ' *Acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved goods, services, production processes or delivery methods*'. In the CIS3 similar information was asked in question 9.1 where the it was asked whether in 2000 the enterprise engaged in the following activity: '*Acquisition of machinery and equipment (including computer hardware) in connection with process or product innovation'.*
Also the response rates for the two questions were different. 939 responses were recorded in the CIS4 round while only 459 in the CIS3 round.Slightly different definitions were given in the 4 questions concerning the introduction of wider innovations(e.g. examples of practices especially in organizational and management innovations) during the three year period proceeding the survey. However, in the context of this study we do not see these changes as particularly significant to impede the comparison over time.

Table 12 - Degree of persistency of innovative activity: CIS3-CIS4 panel (proportions)

	Proportion of innovators in CIS4 (1)	Proportion of innovators in CIS3 (2)	Test of association $^2_{v=1}$ (p-value) (3)	Proportion of CIS4 innovators that introduced the same innovation also in CIS3 (4)	Establishments that introduced no innovation in either CIS3 or CIS4 (5)
Prodinov	0.30	0.39	80.24 (0.000)	0.46	0.50
Procinov	0.25	0.30	49.09 (0.000)	0.41	0.57
Machinery[a]	0.72[a]	0.57[a]	4.68 (0.030)	0.75	0.12
Strategy	0.57	0.26	9.44 (0.002)	0.66	0.34
Management	0.47	0.25	20.57 (0.000)	0.61	0.42
Organiz	0.56	0.33	53.63 (0.000)	0.73	0.35
Marketing	0.57	0.29	19.21 (0.000)	0.69	0.33

NOTE: [a] The two proportions cannot be compared as the variable's definition in the CIS3 has been changed in the CIS4 survey.

The third column of table 12 reports the ^{2} test of association between the decision to introduce an innovation in either, both or neither periods. For all the innovations under scrutiny the test indicates that the decision as to whether introduce an innovation, is not independent of the decision taken in the previous period. This can be better seen in column 4 that reports the proportion of the establishments that introduced the same innovation in the period 2002- 2004 as well as in the period 1998-2000. The degree of persistency of innovative activity is particularly high for all 'wider' innovative activities and the introduction of technological innovations. The proportion of establishments that has introduced a product or process innovation in both periods is slightly lower. This probably reflects the different nature of process or product innovations whose life cycle and complexity can be higher than for wider innovations.

8. CONCLUSIONS

In this study we have used the information contained in the 4th Community Innovation Survey (CIS4) to explore the pattern of use of innovations in UK industry and to test for the existence of complementarities among a range of innovative activities, namely; process, product, technological, marketing, organizational, management and strategic innovations.

By the means of econometric tools we have tested the existence of synergistic effects among the innovative activities of the firm after controlling for the presence of lurking factors and spurious correlations (see the Arora and Gambardella (1991) and Arora (1990) technique) The significance of payoffs from joint adoption was modelled by the means of factor analysis based upon the tetrachoric representation of the payoffs, which has lead us to identify two major sets of innovations. The most important includes 'wide' innovative activities such as marketing, organizational, management and strategic innovations, the second set comprised more 'traditional' activities such as process, product and technological innovations.

A two step cluster analysis based upon the intensity of 'wide' and 'traditional' innovative activities (i.e. standardized factors scores) was carried out leading to the identification of three clusters of firms each reflecting the intensity of use of the two sets of innovations. This was particularly interesting as it showed that wider innovations (strategic, organizational, management and marketing innovations) and traditional innovations (product, process and technological innovations) are complements and not substitutes for each other. In particular, a cluster was found whose intensity of use of the two sets of innovation was below average. This is also the largest cluster containing about 50% of the firms in the sample. A second cluster (containing about 23% of the establishments in the sample) was found with intermediate but above average use of the innovative activities. Finally a third cluster (containing about 19% of the establishment in the sample) was found, made up of highly intensive users seemingly capable of fully exploiting the synergistic effects generated by joint adoption of traditional and wider innovations.

A number of intra cluster firm characteristics have been analysed in order to establish the characteristics of the most innovative firms. We found that the within cluster size composition is quite heterogeneous, the relative importance of large firms is highest in the third cluster; and the majority of small firms tend to populate the first cluster.

We also found no significant differences across the three clusters in the percentage of recently established establishments[12].

We found that the proportion of establishments that carry out in house R&D and the proportion of enterprises that carry out regular training increases progressively from cluster 1 to 3. The proportion of employees with a degree either in science and engineering or other subjects increases going from cluster 1 to 3, confirming the importance of the link between innovation and skills emphasised by, among the others, Bartel and Lichtenberg (1987), Caroli and Van Reenan, (2001), Bresnahan et. al. (2002).

[12]On the grounds that young firm are innovative in all dimensions and this might bias our results we have checked their robustness by re-running our analysis excluding those firms established after 2000 (2788 observations). The tetrachoric correlations do not substantially change.

The percentage of firms that received public support increases with the extent of innovative activity carried out by the firm, reaching a peak of 25% in the highly innovative group (cluster 3). The proportion of firms that are part of a group (versus independent establishments) is highest in the cluster of high innovators than in the other clusters. No significant differences across clusters has been found with respect to whether the market for the firm's final product is international or whether the company belongs to the service rather than the production sector. We also found that establishments operating in the service sector are no more intensive users than other firms in the production sector. Within the production sector mining and quarrying, electricity, gas and water supply and construction are the least intensive innovators but overall the highest percentage of low intensity users are in two service sectors, retail trade and hotels and restaurants. By contrast, high technology sectors such as manufacturing of electrical and optical equipments, manufacturing of transport equipments are the sectors with the highest relative number of intensive users.

In terms of the impact of innovation upon firm performance, due to the lack of a time dimension to the data and the strong potential endogeneity of several of the variables in the CIS4 questionnaire, we have not been able to use statistical inference to assess this impact. So we have looked at the establishments' own estimates of the effect of the introduction of product and processes in increasing value added. The results clearly show that the largest share of those who reported 'high importance' (44.13%) are in cluster 3 while the largest proportion of the 'not relevant' (54.55%) can be found in the least innovative cluster which is also the largest cluster.

In order to investigate whether firms that are innovative are also continuously innovative we have compared the extent of innovative activity reported by the cohort of firms in the CIS4 and the CIS3 survey. The findings reinforce our views as to the impact of innovations - intertemporal persistence is important to performance. Although the extent of product and process innovation remains largely unchanged in the two time periods, the intensity of use of wider innovations has almost doubled. This confirms that wider innovative activities do play a key role in the innovative activity of the firms and in the generation of the benefits from innovation, the study having also shown earlier that wide innovations are responsible for a large part of the pay-offs generated by complementarities and synergies derived from the joint use of the 7 innovative activities.

We conclude that 'traditional' and wider innovation activities should no longer be studied in isolation. A new integrated approach to the innovative activity should be taken in both theoretical and empirical research.

References

Arora A. (1996) " Testing for complementarities in reduced-form regressions: A note," *Economics Letters*, Elsevier, vol. 50(1), pages 51-55.

Arora A. and A. Gambardella (1990) " Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology," *Journal of Industrial Economics*, Blackwell Publishing, vol. 38(4), pages 361-79.

Ástebro T. (2002) “Non-capital investment costs and the adoption of CAD and CNC in US metalworking industries”, *Rand Journal of Economics*, 2002, 33, pp. 672-688.

Astebro, T. (1995), “The Effect of Management and Social Interaction on the Intra Firm Diffusion of Electronic Mail Systems”, *IEEE Transactions on Engineering Management*, 42, 4, 319 –331.

Battisti G. (2000) *“The intra-firm diffusion of new technologies”*, PhD Thesis, Warwick University

Battisti G., Colombo M.G., Rabbiosi L. (2005) '*Complementarity Effects in the Simultaneous Diffusion of Technological and Organisational Innovations*', WP.05.03, Quaderni CIRET, pp.1-29, CIRET-Dipartimento di Ingegneria Gestionale, Universita' Politecnico di Milano - Italy.

Battisti G. and A. Iona (2006.a) ‘*On the Main Drivers of the Adoption of Management Practices: Theory and Evidence from UK Establishments*’, mimeo, p.1-31.

Battisti G. and A. Iona (2006.b) ‘*Can Management Practices Explain the UK Productivity Gap? A Review of the Evidence from the Adoption of Management Practices*’, Aston Business School Working Paper, RP number: RP0632: ISBN No:1 85449 619 0

Black SE, Lynch L. (2004) What's Driving the New Economy? The Benefits of Workplace Innovation, Economic Journal, Vol.114(493), 97-116

Bloom N. and Van Reenen J. (2006), “*Measuring and explaining management practices across firms and countries*”, AIM Seminar, London 24 January 2006

Bresnahan TF, Brynjolfsson E, Hitt LM. (2002) Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence. *Quarterly Journal of Economics*, 117(1); 339-376.

Brynjolfsson E, Hitt LM, Yang S. (2002) Intangible Assets: Computers and Organizational Capital.*Brookings Papers on Economic Activity*, Vol. 1, 137-81

Cappelli P, Neumark D. (2001) ‘Do "High-Performance" Work Practices Improve Establishment- Level Outcomes?’ *Industrial and Labor Relations Review*, Vol. 54(4); 737-775

Caroli E. and Van Reenen J. (2001), “Skill-biased organisational change? Evidence from a panel of British and French establishments”, *The Quarterly Journal of Economics*.

Cohen, W. and D. Levinthal (1989), ‘Innovation and Learning: the Two faces of R&D, *Economic Journal*, 99, 569-96.

Colombo M.G. and M. Delmastro (2002),"The determinants of organisational change and structural inertia: Technological and organisational factors", *Journal of Economics & Management Strategy*, 11, pp. 595-635.

Colombo M.G. and R. Mosconi (1995) "Complementarity and cumulative learning effects in the early diffusion of multiple technologies", *The Journal of Industrial Economics*, 63, pp. 13-48.

Edwards T., Battisti G., and Neely A. (2004), "Value creation and the UK economy: A review of strategic options", *International Journal of Management Reviews,* Vol. 5/6 *Issue n.3&4.*

ESRC Seminar Series (2004), "*Mapping the public policy landscape. The UK productivity gap. What research tells us and what we need to find out*".

Griffith R. and Harmgart H. (2005), "Retail productivity", *International Review of Retail, Distribution and Consumer Research vol.15 (3), 281-290*.

Griffith, R, Harrison, R, Haskel, J and Sako, M (2003), "*The UK productivity gap and the importance of the service sectors*", Advanced Institute of Management (AIM) Briefing Note, December.

Hannah T.H. and J.M. McDowell (1984) "The determinants of technology adoption: The case of the banking firm", *Rand Journal of Economics*,15, pp. 328-335.

Huselid M (1995), "The impact of human resources management practices on turnover, productivity and corporate financial performance", *Academy of Management Journal* 38 (3), 635-872.

Ichniowski C. and Shaw K. (1995) "Old dogs and new tricks: Determinants of the adoption of productivity-enhancing work practices", *Brookings Papers on Economic Activity: Microeconomics*, Spring, pp. 1-65.

Ichniowski, C. Shaw and K. Prennushi, G. (1997), "The effects of human resource management practices on productivity: a study of steel finishing lines, *American Economic Review* vol 87 (3), 291-313.

Karshenas M. and P. Stoneman (1993) "Rank, stock, order and epidemic effects in the diffusion of new process technologies: An empirical model', *Rand Journal of Economics*, 24, pp. 503-28.

Little J. S. and R. K. Triest (1996), 'Technology Diffusion in U.S. Manufacturing: The Geographic Dimension' in Fuhrer J.C. and J. S. Little (Ed), *Technology and Growth.* Conference proceedings, Federal Reserve Bank of Boston.

Mansfield E. (1968) *Industrial research and technological innovation*, New York: W.W. Norton.

McKinsey (1998), "*Driving productivity and growth in the UK economy*", McKinsey Global Institute.

Milgrom, P. and J. Roberts (1990) "The economics of modern manufacturing: Technology, strategy, and organisation", *American Economic Review,* 80, pp. 511-28.

Noteboom B. (1993), 'Adoption, Firm Size and Risk of Implementation', *The Economics of Innovation and New Technology*, Vol. 2, pp. 203-216.

O'Mahony, M and de Boer,W (2002), "Britain's relative productivity performance: has anything changed?", *National Institute Economic Review,* January.

Porter, M.E. and Ketels, C.H.M. (2003), "UK Competitiveness: moving to the next stage", *DTI Economics Paper No.3* (May).

Reynolds J., Howard E., Dragun D., Rosewell B. and Ormerod P. (2005), "Assessing the productivity of the UK retail sector", *International Review of Retail, Distribution and Consumer Research, vol.15 (3) July.*

Ruigrok W, Pettigrew A, Peck S and Whittington R, (1999) "Corporate Restructuring and New Forms of Organizing: Evidence from Europe", *Management International Review*, Special Issue,199/2, pp 41 - 64.

Saloner G. and Shephard A. (1995), 'Adoption of Technologies with Network Effects: an Empirical Examination of the Adoption of Automated Teller Machines', *Rand Journal of Economics*, Vol. 26, (3), 479-501.

Stoneman P. (2004), "Path Dependency and Reswitching in a model of Multi -Technology Adoption" in Guinnane T, Sundstrom W and W. Whatley (eds.), *History Matters: Essays on Economic Growth, Technology and Demographic Change*, Stanford University Press, 2004, pp.36 - 62.

Whittington R, Pettigrew A., Peck S., Fenton. E. and M. Conyon (1999): "Change and Complementarities in the New Competitive Landscape: A European Panel Study, 1992 - 1996", *Organisation Science*, 10, (5), pp. 583-600

APPENDIX 1 - 1992 SIC CODES BY WIDE INDUSTRY GROUPING

CODE	*Industry*
10	Mining of Coal
11	Extraction of Oil and Gas
14	Other Mining and Quarrying
15	Food & Beverages
16	Tobacco
17	Textiles
18	Clothes
19	Leather
20	Wood
21	Paper
22	Publishing
23	Coke, Petroleum & Nuclear Fuel
24	Chemicals
25	Rubber and Plastic
26	Other Non-Metallic Mineral Products
27	Basic Metals
28	Fabricated Metal Products
29	Machinery and Equipment
30	Office Machinery and Computers
31	Electrical Machinery
32	Radio, Television & Communication
33	Medical / Optical Instruments
34	Motor Vehicles
35	Other Transport
36	Furniture
37	Recycling
40	Electricity, Gas and Water Supply
41	Collection, Purification & Distribution of Water
45	Construction
51	Wholesale
60	Land Transport
61	Water Transport
62	Air Transport
64	Post & Telecommunications
65	Financial Intermediation
66	Insurance & Pensions
67	Financial Intermediation (Activities Auxiliary)
70	Real Estate
71	Renting of Machinery and Equipment
72	Computer & Related Activities
73	Research & Development
74	Business Activities

Ref: DIUS Research Report 09-08

www.dius.gov.uk/research

Published by the Department for Innovation,
Universities and Skills

Department for
Innovation,
Universities &
Skills