Mixed mode and organizational innovations in the performance of firms. An analysis of Innovation Survey and Annual Business Inquiry data

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Abstract

The paper explores micro-level innovation survey data and examines the role – vis-à-vis traditional forms of science and technology related activities – which organisational and managerial changes, qualified staff and network capabilities play in determining business performance and the functioning of national systems of innovation. It follows a two-step strategy. First, measures, based on factor scores, of innovation modes are developed and linked to differences in the innovation environments of the OECD countries. Second, the relative importance for firm performance – turnover and value added per capita – of innovation modes (vis-à-vis one another) are tested. A key finding of the paper is that productivity measured by value added per capita is influenced more strongly by non-technological modes of innovation that prioritise internal enhancements to do with organisational and managerial techniques and methods, than it is by improved production processes. Whereas output per capita is relatively more strongly and significantly related to product, process and technology based innovation.

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1. Introduction

This paper examines the important role which organisational and managerial changes and network capabilities play – relative to, or in connection with, other forms of science and technology related activities – in explaining business performance and the functioning of national systems of innovation. It uses a new set of typologies on mixed modes of innovation and tests for their relative effects on enterprises' performance, including productivity measured by both turnover and value added and thus on national economic outcomes.

The context of the study is the following. Innovation is an interactive process. It relies on information and knowledge – some of which is directly concerned with the generation of new/codified scientific knowledge or technological capabilities, for example, activities carried out in R&D labs. As part of the interactive innovation process, such knowledge is generated in specific locations and diffused. The diffusion process involves the transfer of knowledge across units and subsidiaries of the same firm. It also – and increasingly so – involves the transfer of knowledge across different firms, industries and national frontiers (Hagedoorn, 1995, 2002). The importance of linkages in the innovation process has given rise to the notion of systems of innovation (Freeman, 1995, 2002; Lundvall, 1992; Nelson, 1992, 1993).

The process of transferring scientific and technological knowledge requires a different type of knowledge which is linked to new forms of organisational structures – network capabilities – and managerial competencies. Moreover, other factors, such as the advances in ICTs , the importance of services in most countries' GDPs contribute to the relevance of managerial capabilities and workforces education and capabilities. The distinction between these two types of knowledge – science and technology on the one hand and managerial/organisational on the other hand – has led to new typologies of innovation modes, for example, the 'Science, Technology and Innovation' mode (SIU) and the 'Doing, Using and Interacting' mode (DUI) (Jensen et al, 2007). Both, activities linked to SIU and DUI are associated with increased performance (Jensen et al., 2007), and so has traditionally been the combination of product, process and organisational innovations (Geroski et al., 1993). This work contributes to a developing field of study that involves measuring innovation by defining mixed modes through the use of exploratory multivariate analysis of innovation survey data (e.g. Jensen et al., 2007; Battisti and Stoneman, 2007; Hollenstein, 2003; Lambert and Frenz, 2007, 2008; Peeters et al, 2004; Srholec and Verspagen, 2008).

This paper is part of the most comprehensive exercise of such a nature – comprehensive in terms of the breadth of innovation related activities and in terms of the micro-data sets and number of countries involved. It is an extension of a wider OECD micro-data project (Frenz and Lambert, 2009) which uncovers indicators of mixed modes of innovation for a varied group of countries: Austria, Brazil, Canada, Denmark, France, New Zealand, Norway, South Korea and the United Kingdom. This work led to the following typology of innovation modes, broadly similar across the countries: *(i) new-to-market innovating based on own technology; (ii) marketing-based imitating; (iii) process modernising; and (iv) wider innovating based on organisational and marketing activities.*

The aim of this paper is to shed further light on the relative importance of the four mixed modes of innovation in explaining the performance of the enterprise; for the UK only at this stage. Performance indcators used are levels of productivity measured both as output and value added Data are derived from matching the fourth and fifth Community Innovation Surveys in the UK (UKISs) with the latest waves of the Annual Business Inquiry (ABI 2005), which provide output and value added data. Analysing the linked observations, the paper contrasts the relevance of science and technology related innovations with 'softer' capabilities to do with organisational and business processes, managerial knowledge and collaborative activities and of STEM and non-STEM qualified human resources.

The paper is organised as follows. Section 2 provides the theoretical context for the importance of new approaches to uncovering modes of innovations. Section 3 briefly discusses the typology of innovation modes derived from the OECD micro-data project. The relative importance of modes of innovation in enterprises' performance is then tested in the reminder of the paper. To this end, Section 4 discusses the methods and data used, which lead to the results on firm performance presented in Section 5. Section 6 concludes and discusses the key findings.

2. Theoretical context

2. 1 Non-technological innovations

Historically, studies into the determinants and effects of innovation were confined to technological activities (e.g. Cohen, 1995; Smith 2005) and studies of innovation focused on only two Schumpeterian definitions of innovation: the introduction of a new product and the introduction of a new production process (Schumpeter, 1934). Early linear models of innovation processes examined such innovations as the outcomes of a technology-push. On the empirical side, readily available data measuring innovation – R&D and patent statistics – perhaps reinforced the emphasis on technological activities.

A perception that R&D investment by business and public sector bodies provided only a partial account of the processes and resources needed for innovation, both at the level of the firm and the economy overall, lay behind the development of international guidance on broader measures of innovation set out in the successive revisions of the Oslo manual (OECD, 1996, 2005). This publication, developed by national experts on innovation measurement, embodies a view that is significantly influenced by ideas that tend to be brigaded under the heading of 'national systems of innovation'.

In particular, the manual and the innovation surveys based on it have developed to include more systematic coverage of the links between agents through information flows and collaboration on innovation projects, whether or not these are via markets or other mechanisms. There has also been increasing attention to the domains of non-technological innovation, including organizational, business process and marketing changes as part of the re-positioning of businesses.

In parallel with these developments at the data level, innovation in business structures, independently of, or in conjunction with, new or changed product offerings or processes for production and distribution, has been the subject of much study in the management literature, but perhaps has attracted less attention in the economics of innovation. The dominance of services – broadly defined – in the national income of modern economies has not, perhaps, yet been fully reflected in the economic theories and empirical studies of innovation (Howells and Tether, 2007). This may be because the distinction can be overstated – attempts to simply characterize 'services' as distinct from production, for example, as involving usually some personal relationship in the supply (e.g., hairdressing, restaurants) miss-specify important 'service' industries which generate impersonal services delivered anonymously (e.g., software, pension fund management). However the concern with taking proper account, in theory and analysis, of the variety of products, markets and enterprises, including the rather heterogeneous collection of 'services' sectors, does motivate a search for models of innovation behaviour, and of its economic impacts, that do not rest so much on technology alone.

A last point worth of mentioning is the attention paid in the literature to IT investment, e.g. in personal productivity and communications software and logistics (Brynjolfsson and Hitt, 1996, 2000). Recent works matched innovation and IT surveys for the purpose of modelling the relevant relationships (Clayton, 2008).

The richness of the data obtained from the Oslo manual based innovation surveys enables models of the complementarities between all types of innovation directed investment and organizational change to be estimated. These models can also include the mediating or conditioning role of the linkages in the innovation system.

2.2 National Innovation

The size and significance of the impact of innovation as a determinant of national economic performance is clearly of immense policy interest. This issue has often been investigated at the aggregate level, using growth accounting or knowledge production function models where innovation has been proxied by the stock or flow of R&D spending or the stock of patents in a country. More sophisticated variants take account of the role of embodied technical change and improvements in skills, through augmented labour and capital measures. Recent studies try to incorporate a wider set of intangible investments into these aggregate models (e.g., Calyton et al., 2008).

The increasing availability of micro-data, based on innovation surveys and other sources, enables an alternative route to estimating the relationships between economic outcomes – growth, productivity, employment etc. – and a more finely grained set of innovation indicators. A body of such research is being co-ordinated through an on-going set of projects under the auspices of the OECD's NESTI committee. One strand of work – Criscuolo (2009) and Therrien and Hanel (2009) – is applying what might be thought of as the micro-data version of the augmented aggregate production function models outlined above, by using a framework proposed by Crépon, Duguet and Mairesse (1998) – the CDM model.

A second strand of the research, developed further in this paper, adopts a novel way of taking account of a wider set of complementarities in innovation, by measuring a set of mixed modes by factor analysing innovation survey data. It is an extension of an earlier phase of the OECD project (Frenz and Lambert, 2009) which uncovers indicators of mixed of innovation for nine countries. The rationale for the modelling strategy is briefly, that patterns of innovation at the micro level can be investigated with statistical techniques that allow "centres of gravity" of firm and industry behaviour to emerge from the wealth of data in the broad brush innovation surveys.

The alternative approach to compiling indicators that take account of technological, non-technological and organizational forms jointly is to impose a set of categories (e.g. Evangelista and Vezzani, 2008). This has the merit of enabling theoretical expectations to be included directly, but at the cost of ignoring large amounts of potentially relevant information.

The empirical part of the paper extends the model to more recent evidence, for the UK only at this stage. Data are derived from matching two sources: the fourth and fifth UK Innovation Surveys (UKIS 2005 and 2007) with the latest waves of the UK Annual Business Inquiry (ABI 2005). Analysing the linked observations, the paper contrasts the relevance of science and technology related innovations with 'softer' capabilities to do with organisational and business processes, managerial knowledge and collaborative activities. Two different measures of productivity performance derived from the ABI are considered, based on turnover and value added per capita.

3. Mixed modes of innovations and productivity

3.1 Mixed modes of innovation

Some recent approaches to measuring innovations are based on exploratory multivariate analyses which provide a relatively parsimonious technique for deriving modalities that show the integration and complementarities between the range of inputs and outputs. The most comprehensive approaches to simultaneous micro-data studies comparing patterns across countries are those undertaken by the OECD micro-data project (OECD, 2009).

This section provides an overview of the advances made towards formulating typologies of mixed modes of innovation. For a detailed discussion on methodology and findings, and to access the individual factor loadings for the participating countries, see Frenz and Lambert, 2009. Table 1 provides an overview of the four mixed modes of innovation across nine OECD countries.

Table 1 here

The common patterns – typologies of modes of innovation – derived from the factor analyses are summarised and interpreted in the first column of Table 1. They are: *i) new-to-market innovating based on own technology; ii) marketing-based imitating; iii) process modernising; and iv) wider innovating.* The highest degree of country specificity is found in the 'new-to-market innovating' mode, (interpretation of the first row in Table 1). Thus, heterogeneity is greatest in the case of modalities of innovation leaning towards the frontier of innovativeness. While all countries exhibit one or two distinct factors which can broadly be summarised into 'new-to-market innovating' the extent to which, for example, design activities and diffused technologies matter, differs across nations. In Austria, Denmark and New Zealand diffused technology (externally acquired R&D) is commonly found in conjunction with own technology. We see this as an indication of a more open innovation pattern in these countries. In Austria, Brazil, Denmark, Korea and Norway, design-related activities are associated with new-to-market innovating, in addition to internal capacities generated by in-house R&D. In such cases, innovation is relatively design-led (vis-à-vis other countries).

A contrasting pattern – also linked to new-to-market innovating – foregrounds appropriation strategies, which feature strongly in results for Canada, France, New Zealand and the United Kingdom. It seems likely that such firms rely to a greater extent on closed innovation practices where new-to-market innovations are solo activities based on internal capabilities coupled with firms' emphasis on protecting internal knowledge from copying/use by others through IPRs.

In case of the UK, the factor 'new to market innovating' rests particularly heavily on appropriation strategies. The UK, one of the largest economies in Europe, is a country with a strong innovation environment and advanced innovation system, specifically in an historical context (e.g. Freeman, 19xx), which may explain why the

UK leans more strongly towards appropriation strategies compared, for example, with the smaller, Nordic economies.

Almost all countries, the exceptions are Korea and Norway, exhibit a mode associated with ‘marketing-based imitating’ formed by enterprises with ‘new-to-firm product innovations’ and expenditures on marketing. In the case of Brazil, France and the UK, this mode also leans towards the generation of internal capabilities, for example through in-house R&D.

There is greater homogeneity across countries with respect to the last two modes of innovation. Activities considered as ‘process modernising’ – third row in Table 1 – include acquisition of machinery, equipment and software, and, thus, the use of embedded technologies, along with training of staff to apply the new equipment and intangible assets to innovation-related activities. Firms in Austria, Brazil, Canada, Denmark and the United Kingdom importantly exhibit these practices. Technological activities in the form of in-house or acquired R&D generally play a lesser role; however, in Korea one factor/innovation mode links process innovation with internal and external R&D. Organisational and marketing innovations are linked to process modernising in New Zealand and Norway and are referred to as ‘business process modernising’ to acknowledge a strategy which involves changes to production processes in tandem with changes to the organisational structure and managerial techniques and competencies.

All countries suggest an innovation mode which we interpret as ‘wider innovating’. Here, organisational and marketing-related innovation strategies load up in one factor for firms in Austria, Brazil, Denmark, and the United Kingdom. In France and Korea, two separate factors involve organisational innovating on the one hand and marketing innovating on the other hand.

3.2 Mixed modes of innovation and productivity

The OECD micro-data project reports contain some preliminary results linking the four mixed modes of innovations ‘new-to-market innovating’, ‘marketing-based imitating’, ‘process modernising’ and ‘wider innovating’ to levels of productivity – turnover per employee – for the eight out of the nine participating countries. The results are mixed. There is one innovation mode related to levels of productivity in all of the participating countries (except for Denmark), and in the majority of cases – four out of seven – it is the mode titled ‘process modernising’. In Austria, Brazil, Canada and Norway process modernising is associated with higher productivity levels. This is a finding that one would expect; advancements in production processes or the delivery of services are linked to increased efficiencies.

A different pattern emerges in New Zealand and the United Kingdom with positive associations between ‘new-to-market innovating’ – in both cases the factors are that of relatively closed innovation patterns – and productivity. Similarly, in Norway, ‘technology producing and using’ – factor unique to that country, is positively linked to productivity. That different innovation modes are significantly related to the level of productivity, measured at the end of the three-year period covered by the surveys, suggests that, even with datasets constrained to be as comparable as possible across participating countries, there are major national differences in patterns of competitive and comparative advantage. This would imply, for example, potentially different responses to similar policy instruments.

3.3 Extension to the productivity analysis

The analysis above is constraint in a variety of ways. First, all results are restricted to encompass innovation active firms only – while non-innovation active firms are omitted from the estimations (because most countries only collect information on the relevant variables for innovation active firms). Constraining the sample to exclude non-innovation active firms will have biased the estimates capturing the impact on productivity of innovation modes towards zero; and, one explanation towards finding fewer relevant associations between innovation modes and productivity.

Second, the effects of innovation strategies may feed into productivity with a time delay. Innovation modes are measured over a three year period, 2002-2004, and productivity is measured in 2004. Third, important explanatory variables are omitted from the regression – specifically variables related to human capital and capital expenditures, which, too, affects the coefficients of the four mixed modes.

The remainder of this paper analyses the relationship between the four mixed modes of innovation and different measures of productivity for the UK, with the aim to address the three limitations of the previous work as discussed above. First, the estimations in this paper are based on the complete UK sample of innovation and non-innovation active firms. Second, the paper uses the panel between UKIS2005 and UKIS2007 to allow for a lag in the relationship of innovation and productivity. Third, the model includes a much wider range of independent variables in the productivity equations including capital expenditures, measures of human capital – STEM and non-STEM skills – and twelve regional dummies. Moreover, this paper measures productivity both as turnover and value added per capita.

4. Data and methodology

4.1. Data

The data derives from the fourth and fifth UK Innovation Surveys (UKIS) and the latest Annual Business Inquiry (ABI) 2005. The unit of analysis is the enterprise, which is the smallest legally independent unit of a firm. The data contains all manufacturing and private services. Micro firms – enterprises with fewer than 10 employees – are not included in the surveys.

Variables feeding into the factor analysis, and forming our four mixed modes of innovation, are from the UK survey of 2005, reporting innovation investment and outcomes in 2002-2004 – the reference period. In order to test for a time lag between modes of innovation and impact on performance, the UKIS2005 is linked to levels of productivity measured in 2006 (the reference year for UKIS2007 (reference period 2004 to 2006). The modal analysis of UKIS 2005 data is also linked in the productivity equations to the latest available ABI which provides information for the year 2005. Specifically, the ABI provides measures of value added and capital expenditures. We regress productivity on the four mixed modes of innovation based on three datasets: (i) UKIS2005; (ii) panel between UKIS2005 and 2007; and (iii) linked database between UKIS2005 and ABI2005. While the OECD project restricts the sample – due to availability issues – to innovation active enterprises, all analyses in this section are based on the full UKIS sample.

The sample sizes across the three datasets differ. The UKIS2005 is a representative, random sample with 16,441 observations, the panel between the two innovation surveys (n=7,069) and the overlap between UKIS 2005 and ABI (n=4,907) are biased towards large and more innovation active firms. We compare the coefficients based on UKIS2005 to test the sensitivity of the results on the change in sample. The observations reported in the regression equations are slightly lower than the figures reported here due to partial missing values affecting some of the questionnaire items.

4.2 Method

All variables feeding into the factor analyses are measured on a binary scale. If an enterprise engaged in a specific innovation related activity, for example reporting a new-to-market product during the reference period of the survey, then the variable new-to-market product innovation is coded 1, otherwise 0.

The binary data factor analysis involves the computation of a tetrachoric correlation matrix, and factor analysing this matrix, under the assumption that the observed binary variables correspond to latent continuous variables. An advantage of factor analysis is that it provides indicators in the form of factor scores, regression methods were used to compute the factor scores, which have a low degree of correlation (Fidell and Tabachnick, 2006).

The factor scores are used directly as explanatory variables in regression models which estimate the relationship between modes of innovation and productivity. We use OLS, computing robust standard errors, predicting levels of productivity per capita based on the four modes of innovation introduced above. One regression is based on the representative and larger IS2005 sample and a second model on the innovation survey panel to incorporate lags or leads into the model. The final two models use innovation survey data and the ABI data. We test the linear hypothesis of equality of coefficients in connection to the modalities of innovation.

Next to the factor scores, further independent variables include cooperation activities, and different types of skills. In the regressions, and to the extent that information is available, we control for capital expenditures and employees' skills in STEM and non-STEM areas, organisational characteristics (including group belonging, size and sector), a firm's market, size, sector and location within the UK.

4.3 Variables

The variables used in the factor analyses include product innovation, process innovation, marketing and organisational innovation, own technology, diffused and embedded technology, design and other inputs. Appendix A contains a summary table of the set of variable on the basis of which modes of innovation practices are identified.

Measures of productivity form the dependent variables. First, productivity measured as turnover per employee for the year 2004 and for the year 2006. For normalization purposes the variable is log transformed. Second, productivity is measured as value added per capita. At the time of running the regressions, we used the latest available data which – in the UK – is 2005. After correcting for outliers, this variable is approximately normally distributed.

The independent variables are the factor scores which measure the four mixed modes of innovation. We use regression method to derive the scores following the factor analysis. The first UK factor – new-to-market innovating – is a 'closed' factor based on IPR and in-house R&D and is referred to in this paper as IPR/in-house innovating. The second factor is that of process modernising, the fourth factor captures wider innovating and the fourth factor market-driven innovating. The factors are produced individually on the three datasets: (i) UKIS2005; (ii) panel between UKIS2005 and 2007; and (iii) linked database between UKIS2005 and AIB2005. The results of the factor analyses are highly similar.[1]

The paper uses a range of control variables when predicting levels of productivity: this include a dummy measuring if the enterprise is part of a wider company group, a dummy measuring if the enterprise perceived the relevant market for its products (goods and services) to be international vs national. There are two indicators of human capital – measured as the log of the proportion of employees with (i) science and engineering degrees and (ii) with other degrees. Two dummies measure if an enterprise collaborated on innovation with another business – supplier, customer or competitor – or if an enterprise collaborated on innovation with the science base – universities, research organisations. Enterprise size is measured as the log of the number of employees. The regressions control for 2-digit industry sectors and twelve UK regions.

Additionally to the above control variables, estimations based on the panel between IS2005 and 2007 contain two variables coded one if the turnover of an enterprise changed due to (i) merger or (ii) acquisition. Finally, the regressions based on the matched dataset IS2005 and ABI2005, contain, as an explanatory variable for productivity, the net capital expenditures per capita – log transformed for normalisation purposes.

[1] Individual results are made available on request.

5. Results

The first estimations reported in Table 2 are based on the UKIS2005: productivity refers to 2004 and modes of innovation are based on variables that refer to the period 2002 to 2004. The descriptive and correlation statistics are in Appendix B, Table B.1.

Table 2 here

Out of the four mixed modes of innovation, three – IPR/in-house innovating, process modernising and wider innovating – are statistically significantly associated with productivity.[2] IPR/in-house innovating has the largest coefficient (b=0.105; p<0.001). Testing the linear hypothesis of equality of the coefficients does, however, not suggest that the impact of IPR/in-house innovating is significantly greater than that of process modernising or wider innovating. Market-driven imitating is the only mode of innovation that does not appear to be associated with increased levels of output per head.

Turning briefly to the control variables, we find that being part of a wider company group, operating in international market, STEM and non-STEM skills are positively and significantly related with productivity. While there is no support for a link between turnover per employee in 2004 and cooperating on innovation – irrespectively of the type of partner (firm or science base) – between 2002 and 2004.

The next set of results examines a possible time lag between modes of innovation and productivity using the panel between IS2005 and 2007. The results are reported in Table 3 below.

Table 3 here

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[2] Compared with the estimates in Frenz and Lambert (2009) which report only IPR/innovating as significantly associated with turnover per employees, there are now three innovation modes which indicate a positive impact on productivity. This result can be explained by the fact that the sample used in Table 2 is not constraint to innovation active firms while the results in Frenz and Lambert (2009) are.

The coefficients for IPR/in-house innovating and wider innovating are positive and statistically significant at the 1% and 10% level respectively. The size of the coefficient for IPR/in-house innovating is almost the same as in Table 2; the coefficient for wider innovating is smaller, while the coefficient for process modernising is almost zero and insignificant.

Table 3 does not support a time lag of two years between the innovation modes and productivity, as this degree of lag does not increase the explanatory power of the equations. The following may contribute towards an explanation of the results: The lag may not be long enough to capture the longer term effects of innovation; or that innovation and productivity are jointly determined and roughly contemporaneous; or that, in a knowledge capital driven model, the stock of knowledge dominates so that current productivity performance is related to cumulative innovation, with current innovations in the market or the firm acting as proxies for the true cumulative variables. Further still, the mixed modes variables may be better proxies than the “raw” variables as they include more sorts of innovation inputs and outputs in combination.

We now turn to Table 4 which reports and compares the results on turnover and value added per capita, while at the same time controlling for capital expenditures, which was not possible in Tables 2 and 3 as the innovation surveys do not contain the relevant information. Instead this variable is taken from the ABI.

Table 4 here

As before, IPR/in-house innovating is positively and significantly associated with turnover. It is also the variable most strongly associated with value added per employee. Market-driven imitating is again not associated with turnover per employee and also not linked to value added per employee.

An interesting pattern emerges with respect to process modernising and wider innovating. The former is positively and significantly related to turnover per employees (as in Table 2) but not to value added per head; while in the case of the latter the reverse is true. Wider innovating is not significantly associated with turnover per employees (albeit very close to the size of the coefficient for process modernising), but with value added per employee.

This suggests that productivity measured by value added per capita is influenced more strongly by non-technological modes of innovation that prioritise internal enhancements to do with organisational and managerial techniques and methods – than it is by improved production processes. Whereas output per capita is relatively more strongly and significantly related to product, process and technology based innovation

This pattern is mirrored, too, in the skills variables. Non-STEM skills – measured by the proportion of degree holders in other disciplines than science and engineering – is positively associated with value added and not with turnover per employee; while the opposite is the case for STEM skills.

It is relevant to note that value added per head is measured in 2005 while turnover per head is measured in 2004. Previously we did not find a two year time lag between process modernising and turnover per head, so this could contribute to the non-significant coefficient of process modernising in the regression of value added. With respect to wider innovating, firms may in fact lose – or rather not increase – efficiency until the full implementation of the new method (e.g. new logistic system) including training of staff.

Capital expenditure is relevant in both equations – turnover and value added per employee, and the results of the remaining control variables are highly similar to those previously reported in Tables 2 and 3.

6. Conclusions and discussion

The paper expands on the OECD micro-data study on developing measures of mix modes of innovation based on factor analysing innovation survey data (Frenz and Lambert, 2009). The emphasis here is on estimating the relative impacts of the mixed modes of innovation on two measures of productivity (turnover and value added per capita). While previous work did not find support for a strong connection between productivity and the mixed modes of innovation which we attribute to important data limitations, the results in this paper suggests that three out of four innovation modes – IPR/in-house innovating, process modernising and wider innovating – all play important roles in increased enterprise performance. Only one mode of innovation, market-driven imitating, showed no association with firm performance.

The core finding in this paper is that productivity measured by value added per capita is influenced more strongly by non-technological modes of innovation that prioritise internal enhancements to do with organisational and managerial techniques and methods – than it is by improved production processes. Whereas output per capita is relatively more strongly and significantly related to product, process and technology based innovation. This result may be hypothesised to indicate that TPP (Technological Product and Process Innovation) tends to increase labour productivity through opportunities for output or cost savings. Non-technologically dominated modes, including the deployment of organisational reforms, allied to staff qualified in non-STEM subjects, are required to enhance value added – including profits and quasi-rents to labour and capital.

While wider innovating (including managerial capabilities) is associated with value added, and process modernising with increased outputs per employee, IPR/in-house innovating is positively associated with both. This finding may be specific to the UK for two reasons. Not all countries exhibit a similar mode of innovation, one which is associated with closed patterns of innovation where the appropriation of innovations is at the core of firms' innovation strategies, and even in countries where such strategies are relevant – mainly the larger economies – another innovation mode, process modernising, more strongly correlates with productivity (Frenz and Lambert, 2009). In the case of the UK, this mode of innovation may indeed capture firms with strong records in innovative capabilities linked to novel goods and services.

A last point worth mentioning is that the paper does not support a time lag between innovation modes and productivity. This may be because the lag used in the paper, 2 years, is not wide enough to capture the long-term effects of innovation or current productivity performance is related to cumulative innovation. Our results shed further light on important patterns which warrants further research into the relevance of mixed modes of innovation for firm performance, including for example longer time lags, indicators of sustained innovation activities and measures of firm level profitability.

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Table 1 Typology of mixed modes of innovation performance across OECD countries

<table>
<tr><th>Modes of innovation</th><th>Austria</th><th>Brazil</th><th>Canada</th><th>Denmark</th><th>France</th><th>Korea</th><th>New Zealand</th><th>Norway</th><th>United Kingdom</th></tr>
<tr><td>New-to-market innovating based on own technology</td><td>Factor 1 based on own and diffused technology, and based on design.</td><td>Factor 1 based on own technology, and based on design.</td><td rowspan="2">Factor 3 based on IPR/external innovating.

Factor 1 in-house/market driven innovating product innovations with own technology and marketing expenditures.</td><td rowspan="2">Factor 1 based on own technology and diffused technology.

Factor 2 new-to-market and new-to-firm innovations with marketing and design.</td><td rowspan="3">Factor 3 based on IPR innovating.

Factor 1 Technology innovating and process modernising. New-to-market, new-to-firm, process innovators, own and diffused technology, machinery and training.</td><td>Factor 1 based on IPR/in-house innovating with own technology and design.</td><td>Factor 2 based on own and diffused technology and marketing.

Factor 3 based on IPR innovating.</td><td>Factor 1 based on diffused technology, excl. own technology. Factor 3 based on IPR/design innovating.</td><td rowspan="2">Factor 1 based on IPR/in-house innovating.

Factor 4 based new-to-firm innovation, marketing expenditures, plus new-to-market, own technology.</td></tr>
<tr><td>Marketing-based imitating</td><td>Factor 4 based on new-to-firm innovation with marketing expenditures.</td><td>Factor 2 based on new-to-firm innovation with marketing expenditures, own, diffused technology.</td><td>No directly associated factor.</td><td>Factor 4 based on new-to-firm innovators with marketing expenditures.</td><td>No directly associated factor.</td></tr>
<tr><td>Process modernising</td><td>Factor 3 based on process innovation, machinery and training.</td><td>Factor 3 based on process innovation, machinery and training.</td><td>Factor 2 based on process innovation, machinery and training.</td><td>Factor 4 based on process innovation, machinery and training.</td><td>Factor 4 process innovation, with technology producing and using.</td><td rowspan="2">Factor 1 Business process modernising based on process innovation, organisational innovation, marketing innovation, machinery and training.</td><td rowspan="2">Factor 2 Business process modernising based on process innovation linked with organisational innovations and not based on machinery and training.</td><td>Factor 2 based on process innovation, machinery and training.</td></tr>
<tr><td>Wider innovating</td><td>Factor 2 joining organisational and marketing activities, plus design.</td><td>Factor 4 based on organisational and marketing innovation.</td><td>N/A</td><td>Factor 3 based on organisational and marketing activities.</td><td>Factor 2 organisational innovations. Factor 3 with marketing activities.</td><td>Factor 2 marketing innovating. Factor 3 organisational innovating.</td><td>Factor 3 based on organisational and marketing activities.</td></tr>
</table>

Source: Frenz and Lambert (2009).

Table 2 Regression results for UKIS2005

	Log turnover per employee *2004*		
Independent variables	*b*	*se*	
IPR/in-house innovating	0.105	0.025	***
Process modernising	0.096	0.026	***
Wider innovating	0.086	0.028	**
Market-driven imitating	0.003	0.025	
Control variables			
Group belonging	0.325	0.021	***
Foreign market	0.271	0.021	***
Log STEM	0.068	0.010	***
Log non STEM	0.050	0.010	***
Cooperation firms	-0.020	0.030	
Cooperation science base	-0.014	0.040	
Log employees	-0.106	0.009	***
Industry dummies	Included		
Region dummies	Included		
Number of observations	12,313		
F-value	59.59	***	
R-squared	0.249		

OLS with robust standard errors; * p<0.10; **p<0.05; ***p<0.01.

Table 3 Regression results for panel between UKIS2005 and 2007

	Log turnover per employee 2006		
	b	*s.e.*	
Independent variables			
IPR/in-house innovating	0.110	0.035	***
Process modernising	-0.005	0.035	
Wider innovating	0.054	0.033	*
Market-driven imitating	-0.019	0.032	
Control variables			
Group belonging	0.241	0.032	***
Foreign market	0.328	0.031	***
Log STEM	0.097	0.013	***
Log non STEM	0.062	0.014	***
Cooperation firms	-0.047	0.044	
Cooperation science base	0.047	0.058	
Log employees	-0.080	0.014	***
Merger	0.012	0.055	
Acquisition	-0.134	0.055	**
Industry dummies	Included		
Regional dummies	Included		
Number of observations	5,363		
F-value	31.26	***	
R-squared	0.305		

OLS with robust standard errors; * p<0.10; **p<0.05; ***p<0.01.

Table 4: Regression results for the merged dataset: UKIS2005 and AIB2005

	Log turnover per employee 2004			Gross value added per employee 2005		
Independent variables CIS4	*b*	*se*		*beta*	*se*	
Factor 1: IPR/in-house innovating	0.094	0.044	**	0.053	1.748	***
Factor 2: process modernising	0.079	0.046	*	0.022	1.991	
Factor 3: wider innovating	0.073	0.051		0.049	2.089	***
Factor 4: market-driven imitating	-0.002	0.046		0.007	1.950	
Control variables CIS4						
Part of a company group	0.413	0.038	***	0.125	1.498	***
International competition	0.231	0.041	***	0.048	1.701	**
Log net capital expenditure	0.136	0.010	***	0.313	0.350	***
Log scientists and engineers	0.034	0.058	**	0.006	2.384	
Log employees with other degrees	0.105	0.068		0.019	3.236	**
Cooperation with other firms	0.037	0.015		0.003	0.607	
Cooperation with the science base	0.018	0.015		0.061	0.602	
Log number of employees	-0.240	0.019	***	-0.307	0.633	***
2 digit industry dummies	Included			Included		
Number of observations	3,568			3,488		
F-value	46.26	***		24.41	***	
R-squared	0.28			0.145		

Note, that the units of measurement between turnover and value added per employee differ; turnover per employee is log transformed while value added per capita is not OLS with robust standard errors; * p<0.10; **p<0.05; ***p<0.01.

Appendix A

Table A.1 Variables feeding into the factor analysis

Description of the variable	**Name of the variable**
Product innovation	
Introduction of a new-to-firm product (not new to the market)	New-to-firm product innovation
Introduction of a new-to-market product	New-to-market product innovation
Process innovation	
Process innovation (methods of manufacturing; delivery or distribution methods)	Process innovation
Organisational and marketing innovation	
New knowledge management system	New knowledge management
Change to the organisation of work, incl. management structure	New organisational structure
Changes in relationships to other firms, incl. partnerships	New relations with other organisations
Changes in design or packaging	New design or packaging
Changes in sales or distribution methods	New distribution methods
Own technology	
Intramural R&D	In-house R&D
Enterprise applied for a patent	Patent
Diffused and embedded technology	
Extramural R&D	Extramural R&D
Expenditure on acquisition of machinery, equipment and software	Machinery
Expenditure on external knowledge acquisition	External knowledge
Design	
Registered industrial design	Design registration
Claim copyright	Copyright
Other inputs	
Expenditure on training	Training
Expenditure on market introduction of innovations	Marketing expenditures

Appendix B

Table B.1 Descriptive statistics and correlations between the variables used in regression Table 3 (CIS4)

	Variables	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11
1	Log turnover per employee	4.22	1.08	-3.93	11.44	1.00										
2	IPR/in-house innovating	0.18	0.42	-0.41	1.16	0.11	1.00									
3	Process modernising	0.28	0.36	-0.78	1.48	0.03	-0.11	1.00								
4	Wider innovating	0.15	0.36	-0.50	1.27	0.05	-0.08	-0.06	1.00							
5	Market-driven innovation	0.10	0.38	-1.02	1.54	0.04	-0.13	-0.02	-0.03	1.00						
6	Group belonging	0.38	0.49	0.00	1.00	0.22	0.18	0.01	0.16	0.08	1.00					
7	Foreign market	0.37	0.48	0.00	1.00	0.21	0.28	0.04	0.06	0.21	0.23	1.00				
8	Log STEM	0.89	1.40	0.00	8.62	0.16	0.26	0.09	0.17	0.15	0.30	0.30	1.00			
9	Log non STEM	1.21	1.52	0.00	9.47	0.11	0.20	0.09	0.21	0.07	0.30	0.19	0.59	1.00		
10	Cooperation firms	0.16	0.37	0.00	1.00	0.05	0.10	0.20	0.17	0.27	0.13	0.16	0.21	0.14	1.00	
11	Cooperation science base	0.08	0.27	0.00	1.00	0.03	0.12	0.17	0.12	0.18	0.09	0.15	0.22	0.12	0.61	1.00
12	Log employees	4.20	1.48	2.30	11.08	0.04	0.20	0.04	0.20	0.03	0.40	0.16	0.45	0.58	0.12	0.09

*N=12,313

Table B.2 Descriptive statistics and correlations between the variables used in regression Table 4 (CIS panel)

	Variables	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Log productivity	4.30	1.09	-2.36	13.65	1.00												
2	IPR/in-house innovating	0.17	0.43	-0.54	1.24	0.15	1.00											
3	Process modernising	0.31	0.40	-0.87	1.60	0.00	-0.11	1.00										
4	Wider innovating	0.15	0.39	-0.59	1.37	0.03	-0.08	-0.10	1.00									
5	Market-driven innovation	0.09	0.43	-1.13	1.56	0.04	-0.13	-0.15	-0.08	1.00								
6	Group belonging	0.37	0.48	0.00	1.00	0.22	0.18	0.00	0.13	0.07	1.00							
7	Foreign market	0.38	0.49	0.00	1.00	0.24	0.31	0.01	0.03	0.18	0.21	1.00						
8	Log STEM	0.91	1.43	0.00	8.06	0.21	0.26	0.08	0.15	0.13	0.31	0.29	1.00					
9	Log non STEM	1.26	1.56	0.00	9.47	0.12	0.18	0.09	0.20	0.05	0.29	0.15	0.59	1.00				
10	Cooperation firms	0.16	0.37	0.00	1.00	0.06	0.11	0.18	0.12	0.26	0.12	0.17	0.21	0.13	1.00			
11	Cooperation science base	0.08	0.27	0.00	1.00	0.05	0.12	0.16	0.10	0.16	0.10	0.14	0.22	0.12	0.61	1.00		
12	Log employees	4.32	1.50	2.30	10.63	0.07	0.17	0.03	0.20	0.01	0.39	0.12	0.45	0.60	0.12	0.09	1.00	
13	Merger	0.06	0.23	0.00	1.00	0.02	0.04	-0.01	0.05	0.02	0.07	0.02	0.07	0.08	0.02	0.00	0.10	1.00
14	Acquisition	0.05	0.22	0.00	1.00	-0.02	0.01	-0.03	0.03	-0.01	0.03	0.01	0.02	0.01	-0.01	0.00	0.02	-0.01

*N=5,363

Table B.3 Descriptive statistics and correlations between the variables used in regression Table 5 (CIS4 merged with AIB2005)

	Variables	Mean	Std dev	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Log turnover per employee 2004	4.39	1.16	1.00												
2	Gross value added per employee 2005	43.31	40.92	0.03												
3	IPR/in-house innovating	0.24	0.44	0.42	0.09	1.00										
4	Process modernising	0.33	0.39	0.41	0.09	0.99	1.00									
5	Wider innovation	0.21	0.38	0.14	-0.05	0.06	0.06	1.00								
6	Market-driven innovating	0.09	0.38	0.06	-0.01	0.04	0.04	-0.09	1.00							
7	Group belonging	0.53	0.50	0.23	0.14	0.14	0.14	0.20	0.03	1.00						
8	Foreign market	0.45	0.50	0.21	0.05	0.08	0.09	0.32	0.06	0.24	1.00					
9	Capital expenditure	4.89	2.93	0.30	0.13	0.19	0.18	0.23	0.09	0.32	0.23	1.00				
10	Cooperation firms	0.20	0.40	0.08	0.21	0.07	0.07	0.13	0.21	0.12	0.20	0.15	1.00			
11	Cooperation science base	0.10	0.30	0.08	0.16	0.07	0.07	0.14	0.17	0.09	0.19	0.12	0.62	1.00		
12	Log STEM skills	1.38	1.74	0.14	0.17	0.10	0.10	0.26	0.11	0.29	0.30	0.34	0.22	0.24	1.00	
13	Log non-STEM skills	1.81	1.83	0.07	0.20	0.10	0.10	0.18	0.10	0.25	0.17	0.37	0.12	0.12	0.63	1.00
14	Log employees	5.17	1.58	0.00	0.21	-0.01	-0.01	0.20	0.04	0.38	0.14	0.60	0.14	0.11	0.42	0.53

*N=3,568