UK COMMISSION FOR EMPLOYMENT AND SKILLS

# Skills and economic performance: The impact of intangible assets on UK productivity

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# Skills and Economic Performance: The Impact of Intangible Assets on UK Productivity Growth

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# Foreword

The UK Commission for Employment and Skills is a social partnership, led by Commissioners from large and small employers, trade unions and the voluntary sector. Our mission is to raise skill levels to help drive enterprise, create more and better jobs and promote economic growth. Our strategic objectives are to:

- Provide outstanding labour market intelligence which helps businesses and people make the best choices for them;
- Work with businesses to develop the best market solutions which leverage greater investment in skills;
- Maximise the impact of employment and skills policies and employer behaviour to support jobs and growth and secure an internationally competitive skills base.

These strategic objectives are supported by a research programme that provides a robust evidence base for our insights and actions and which draws on good practice and the most innovative thinking. The research programme is underpinned by a number of core principles including the importance of: ensuring '**relevance'** to our most pressing strategic priorities; '**salience'** and effectively translating and sharing the key insights we find; **international benchmarking** and drawing insights from good practice abroad; **high quality** analysis which is leading edge, robust and action orientated; being **responsive** to immediate needs as well as taking a longer term perspective. We also work closely with key partners to ensure a **co-ordinated** approach to research.

This Evidence report, which was undertaken by the National Institute of Economic and Social Research, develops our understanding of the role that high-level skills play in improving economic performance and growth. Previous research has shown the links between high-level skills, the production of intangible assets, and increased productivity. This research builds on that work by using firm level data to prove these links at both lower sector and geographic levels. We believe that this study provides a valuable resource to help us understand and demonstrate how skills can improve economic performance.

Sharing the findings of our research and engaging with our audience is important to further develop the evidence on which we base our work. Evidence Reports are our chief means of reporting our detailed analytical work. Each Evidence Report is accompanied by an executive summary. All of our outputs can be accessed on the UK Commission's website at www.ukces.org.uk

But these outputs are only the beginning of the process and we will be continually looking for mechanisms to share our findings, debate the issues they raise and extend their reach and impact.

We hope you find this report useful and informative. If you would like to provide any feedback or comments, or have any queries please e-mail info@ukces.org.uk, quoting the report title or series number.

**Lesley Giles**

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**UK Commission for Employment and Skills**

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# Executive Summary

Improving economic growth is a key policy objective for the Government. Therefore, understanding the drivers of productivity growth is a fundamental requirement for effective economic policy.

Current measurements of productivity, based on the 'tangible' inputs of capital and labour, do not fully account for variations in performance. As a result of this there is a growing interest in 'intangible' assets and their potential to help us to better understand the sources of growth.

Intangible assets are typically grouped into three main categories.

- **Economic Competences** - such as brand equity which would include advertising and marketing expenditures. This category includes firm specific resources, including human capital (investments in training) and organisational structure (management).
- **Innovative Property** - this includes both scientific R&D and non-scientific R&D. Non-scientific R&D includes research in social sciences and humanities, mineral exploration, new motion picture films and other forms of entertainment, new architectural and engineering design and new product development in financial industries.
- **Digitised information** - this is often measured as IT capital, composed of software as well as databases.

Existing studies at the macro level suggest intangible assets make a significant contribution to productivity growth and micro level studies suggest intangible assets help to explain difference in performance between firms.

Because intangible assets are embedded in knowledge workers, and as such are difficult to disentangle from firms' human capital, this research develops measures of intangible assets for UK firms based on the labour input of workers in high skilled organisation, R&D and IT related occupations. These measures are then used to assess how firms employ intangible assets to increase productivity and raise economic performance.

The aims of this research are to explore:

- the number and cost of intangible workers as a proportion of the overall workforce across a range of sectors;
- the relationship between intangible assets and performance; and
- the contribution of intangible assets to growth.

## Approach

Intangibles assets have a number of attributes that make them difficult to measure in an investment framework: they are not always visible; not easily accounted for; and it may not always be easy to fully appropriate the returns. This research uses the number and wages of workers in occupations that are likely to contribute to the production of intangible assets as a basis for a measure of firms' intangible capital stock. These are adjusted to reflect the proportion of worker time invested in the production of intangible goods. Intangible workers are identified using UK Standard Occupation Classification (SOC) codes and are grouped into three categories representing the type of intangible assets they produce.

1 Organisational workers, composed of managers and marketers, reflecting economic competences

2 R&D workers (in broad sense), reflecting innovative property

3 IT workers, reflecting digitised information

The Annual Survey of Hours and Earnings and the Labour Force Survey are the sources of individual occupation and wage data. These are combined with firm level data from the Business Structure Database and Annual Business Inquiry to construct employee and employer data for the period 1998-2006.

This analysis adds to existing research on the role of intangibles in driving growth in a number of ways.

1 The data are constructed using a 'bottom-up' approach, based on firm level estimates of the contribution that wages of intangible rich occupations make to the intangible capital stock of the firm. In comparison to existing studies this gives a great deal of flexibility in analysing intangible assets across geographies and industrial sectors.

2 The analysis focuses on intangible assets that are produced within the firm (i.e. by the firm's own employees) and not purchased from the market (i.e. consultants or outsourcing a firm may use). Often the lines between own account and purchased intangibles is not clear, however own account intangible investments in the UK have often been recorded as accounting for up to half the total investment of intangibles (Awano et al, 2010, p19).

Our analysis of the role that intangible assets play is divided into two components.

- An estimation of sector-specific production functions (using firm-level data), testing for associations between intangible assets and productivity levels. Our findings confirm that there is a positive association between productivity levels and intangible assets as we measure it. These relationships vary across industry sectors and the relative importance of different types of intangible assets (be it R&D, IT or organisation capital) varies too.
- An estimation of the relative contribution to productivity growth made by intangible assets in different sectors and geographies. Productivity growth reflects the rate at which industries or regions are 'improving', i.e. getting more output for less input. Geographic analysis is conducted using 44 city regions (which does not provide total UK coverage but reflects the important functioning economic areas within Great Britain).

### The distribution of intangible workers

Intangible workers make up around 17 per cent of UK workers. This proportion remained broadly stable between 1998 and 2006. The average wage for intangible workers is more than double the average wage for other workers, a gap maintained between 1998 and 2006.

Intangibles are important in most sectors but are dominant in a handful. The findings support the expectation that sectors driven by high technology are likely to have higher levels of intangible assets. However, it is clear that intangible assets are not limited to these sectors. By the nature of the sectors, and the methods used in the analysis, research and development and computers and computing related activities are the two sectors with the highest proportions of workers engaged in the production of intangible assets. Manufacturing also has a high proportion of workers producing intangible assets, particularly the manufacture of medical and optical instruments, communications equipment, office machinery and computers, and the manufacture of chemicals. Sectors linked to energy production, both the mining and quarrying of energy producing materials and electricity, gas and water supply, have a high proportion of workers producing intangible assets.

## Intangible Assets and Performance

Using firm level data, the econometric results indicate that intangible assets have a significant, positive, association with productivity, and that firms with a higher proportion of intangible assets are more likely to be highly productive. The various elements of intangible assets contribute in different ways. Particularly of note is that organisation capital, contributing to economic competences, has a greater impact than either R&D or IT capital. This suggests that a key factor in explaining differences in productivity are due to the way organisations are managed and run.

The total market economy (excluding some sectors) in 1998-2001 and 2003-2006 experienced average annual productivity growth of 2.63 per cent and 3.49 per cent, respectively. The average annual contribution of intangible assets to this growth was 0.46 per cent 1998-2001 and 0.33 per cent 2003-2006. All three intangible categories accounted for a significant share of this, with IT accounting for slightly less than R&D and organisation capital. Organisation capital dominates in market services whilst R&D dominates in manufacturing, despite the use of our broader definition.

Looking across sectors the association between R&D intangible assets and productivity is positive in many sectors, but appears particularly strong in mining and quarrying, and high technology manufacturing. IT capital provides a significant and positive contribution across all sectors. Organisation capital has a significant and positive contribution in nearly all sectors. In more mature, low technology manufacturing sectors (such as wood products or textiles), where R&D is not as significant, organisational capital is particularly important. This illustrates these sectors' reliance on achieving performance increases through process innovation rather than technological innovation.

## Intangible Assets and Growth: sectoral analysis

More often than not, sectors where productivity is rising fastest are sectors where intangible assets make a relatively large contribution to productivity growth.

The growth accounting methodology reveals that the contributions of intangible assets to productivity growth are generally positive. Between 1998 and 2006, intangible assets have been a source of growth for UK firms in most sectors, although the magnitude and composition (across intangible asset types) of these contributions varies across sectors. The sectoral pattern of intangible asset contributions to productivity growth remains broadly stable over time. Organisation capital is more consistent in its importance across sectors compared to R&D and IT.

In production and manufacturing sectors, organisational capital and R&D capital account for a greater impact on growth than IT in general. In high technology sectors such as the manufacture of electrical machinery, medical and precision equipment, and chemicals R&D made the greatest contribution to growth. Whereas, in more mature manufacturing sectors, such as textiles or rubber and plastic products, organisational capital made the greatest contribution to growth.

In service sectors, organisational capital made a greater contribution to growth in more sectors than R&D or IT.

### Intangible Assets and Growth: spatial analysis

The analysis shows that intangible assets contribute positively to productivity growth in the majority of the 44 city regions in both periods: 1998-2001 and 2002-2006. The contribution of intangible assets to growth in each city region varied substantially between the periods. This was true for the contribution of intangible assets overall, and the individual elements.

Still, we note that, particularly in the early period, regions that had the greatest contributions to productivity growth from intangible assets were not the major conurbations and industrial heartlands, but relatively affluent, cities and towns known perhaps for their strong knowledge base (Oxford, Cambridge, Brighton, Norwich) and having relatively good transport links to major conurbations.

### Considerations and Implications

The analysis presented in this report provides an initial exploration of the relationships between intangible assets and economic performance in the UK. Research on intangible assets is a relatively new contribution to the productivity and growth literature and this paper contributes to the discussions that are ongoing. Further work linking skills to occupations will assist in identifying priority skills for future growth. Further research is also needed to move from associations between intangibles and performance to establishing more robust, causal relationships between the two. There is also the need to further disentangle human capital from intangible capital measures.  Another area for further research is the potential for spillovers from intangibles within regions.

# 1. Introduction

Understanding the drivers of productivity growth is seen as a fundamental requirement for effective economic policy in Europe. In recent years, focus has shifted from the nature of the capital input to the nature of the labour input as a key determinant of productivity growth in Europe and the US. Whilst IT was undoubtedly a generic technology that brought with it remarkable changes in production processes, labour was the key to unlocking the real productivity benefits. In addition to direct IT workers, it was also recognised that there were other components of the production system that were gaining importance, and fundamentally, the standard production function approach seemed inadequate for capturing the impact of some of these more intangible inputs.

In recent years, the academic literature has focussed less on the nature of the labour input and more on the concept of intangible assets, which incorporate IT and digitised information, R&D and economic competencies. This latter category captures investments in advertising and marketing as well as training. These assets are heavily dependent on knowledge. Not only are intangibles additional inputs in the production process, but they are investments for future returns and therefore need to be capitalised.

The aims of the research project are to shed light the following questions.

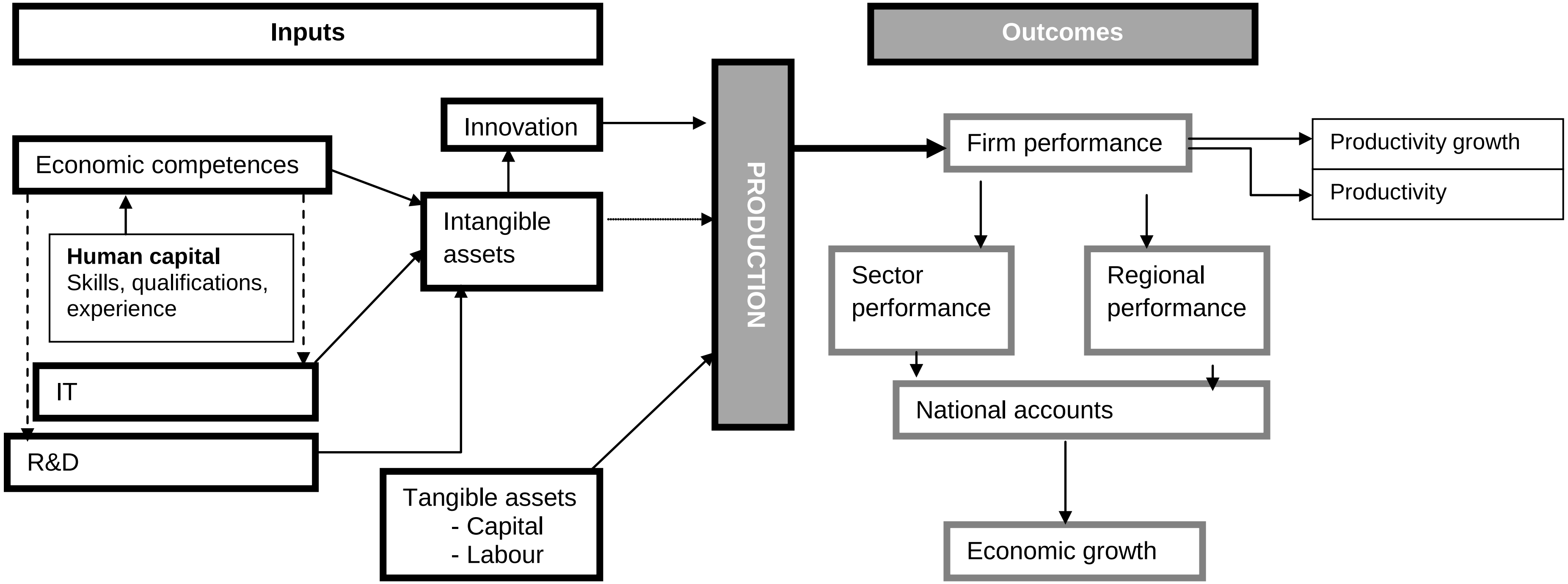
- How have intangible rich occupations evolved over time in the UK?
- Has their evolution varied substantially by industry or region (or country)?
- What contributions do these occupations make to productivity and growth?
- How do the spatial and industrial patterns of dispersion affect performance?

As well as providing a review of relevant literature, the purpose of this report is to provide a discussion of the source and construction of the data and present some initial charts and tables that go some way in addressing the questions raised.

Figure 1.1 offers a schematic of the relationship between intangible assets and outcomes. Whilst a simplification (we exclude many of the complementarities amongst inputs), we also include an indirect effect via innovation. It also recognises the interconnection between IT (and R&D) and economic competences. These have been found to be quite important with respect to the skill biased nature of technological change and the adoption phases of IT (O'Mahony et al, 2008).

The aim of this report is threefold. Firstly, we present contextual evidence from existing literature. This serves two purposes; it provides a greater understanding of the issues under consideration and it provides a broad overview of existing approaches to the measurement and analysis of intangible assets. Second, we go on to provide an overview of the data constructed. The third aim in this study is to look at the associations between intangible capital and performance, captured firstly by looking at firm-level productivity and secondly using growth accounting techniques to explore productivity growth at the regional and sectoral levels. The report is therefore structured as follows: we begin with the review of the literature in Chapter 2. In Chapter 3 we provide a discussion of data requirements and limitations and a description of how firm level measures of intangible capital have been constructed, distinguishing between R&D, IT and organisation capital. Chapter 4 provides detailed econometric estimation of the association between intangible capital and productivity, firstly across all sectors and then individually by approximately 2 digit sector breakdowns (around 20 in the market economy). Chapter 5 presents our findings from the growth accounting exercise to explore the role intangibles play in contributing to productivity growth and the sectoral and regional variation therein. In Chapter 6 we summarise and conclude.

**Figure 1.1: Schematic of intangibles and their economic impact**



# 2. Unpacking intangibles: A review of the literature

**Intangible assets are not new but they have become increasingly important in recent years. This Chapter brings together evidence from the macro and the micro economic perspectives on intangible assets and the contribution they make to productivity growth. We argue that much of intangible capital is embedded in knowledge workers which are complementary to firms' human capital. In addition, gains from intangible capital are likely to have indirect effects in the form of spillovers.**

The birth of the knowledge economy was at first, relatively inauspicious. Whilst hailed as the source of considerable productivity gains, the use of IT generated a productivity paradox (Brynjolfsson, 1993) which puzzled economists. A favourite quip at the time was that 'the computer age [was] everywhere but in the productivity statistics' (Solow, 1987). Over time, there was increasing evidence that the US, a first mover with IT, had experienced a productivity 'miracle', whereby its growth rate reversed the post-war European catch-up trend. This miracle did not appear to travel well. Increasingly, the literature (O'Mahony and van Ark, 2003) confirmed IT as a source of productivity difference between the US and Europe, using the growth accounting approach, but this approach offered little by way of explanation of the causes of the differences. Econometric efforts found it difficult to link IT to the productivity growth in the first place. So whilst undoubtedly some of the productivity divergence between the US and Europe was due to measurement differences of IT inputs in particular, it seemed inadequate in explaining completely the productivity growth divergence (Basu et al, 2004). Attempts to explore links between IT and other assets, particularly skills suggested that the way in which firms have incorporated IT into the production process mattered (Bloom et al, 2007).

At the same time, growth in the availability of micro economic data led to evidence of persistent and large performance differences between firms, suggesting that there was something highly successful firms had more of, than their average counterparts. It became evident therefore, that traditional productivity measurement was missing something. At the macro level, researchers were investigating whether, from an accounting perspective, expenditure on knowledge assets was excluded from national value added calculations.

Here we try to synthesise and bring together these different streams of literature. Firstly we are concerned with the increasing research on intangible assets and their role in national accounts. This takes a very macroeconomic perspective and discusses how a growing but elusive input into the production process – intangibles – should be treated within the standard framework. Secondly, we review firm level evidence of intangible assets and their influence on firm level performance. This explores how intangibles fit with existing theories of the firm; we explore the various dimensions of intangibles, and consider in detail the human capital component. The report focuses primarily on the UK but will draw from the experiences of other countries when appropriate, particularly the US, on which much of the empirical literature focuses. We draw from the economics literature, by and large, but also from management journals, and government reports and international organisations such as the World Bank and OECD.

## 2.1 What is an intangible asset?

**Resource Based Models (RBM) of the firm suggest that firm capabilities, in part defined as intangible assets, account for persistent differences in firms over time. Intangibles comprise of three assets: digitised information, R&D and economic competences. The latter fits into the RBM since economic competences are a firm capability that is not easily traded. At the macro level we note that the existing national accounting framework is more suited to manufacturing production which has become an increasingly small part of developed economies. Intangibles have become more important to growth because of industrial structural change and their importance with respect to the growth in Information and Communications Technology.**

The resource based model of the firm (Teece, 1998) views firms as distinctive bundles of resources and capabilities. These resources and capabilities comprise all of the attributes that enable a firm to conceive and implement strategies, and may be divided into four types (Barney, 1991): financial resources (e.g. equity capital, debt capital); physical resources (machinery, buildings and other tangible assets); human resources (e.g. the knowledge and experience of managers and employees); and organisational resources (e.g. forms of work organisation, innovative work practices and social relations). The two basic assumptions are that these resources and capabilities can vary significantly across firms and that these differences can be stable over time (Barney and Hesterley, 1996). Various reasons may be put forward to explain this potential stability. Two possibilities are that the resources and capabilities are either rare or costly to imitate.

In contrast to the neo-classical approach, the resource-based view focuses more directly on the nature of the inputs to the firm (financial and physical capital, and human resources) and on the internal features of the firm (working practices and structural attributes). Firms may perform below the level of others in their industry either because of a resource gap, in which firms have fewer managerial, technological and other resources than better-performing competitors, or because of a capability gap, in which firms have adequate resources but lack the capabilities to use these resources with maximum effectiveness (Harris and Robinson, 2001: 5). Teece and Pisano (1998) place a particular emphasis on a firm's dynamic capabilities: a subset of its competences and capabilities which allow it to create new products and processes and to respond to changing market conditions. This approach places the innovation process in a prominent position alongside the complementary assets of the firm, which may be clearly identified as intangible assets in the form of economic competences.

Taking a macroeconomic perspective, in the measurement of national accounts, Gross Value Added (or at the national level, Gross Domestic Product, GDP) is equivalent to the value of output, minus the costs of intermediate inputs. Traditionally, all expenditure on intangible assets has been treated as intermediate inputs, which are products from other sectors. To include them as an input and an output in the economy risks double counting. However, it is argued that the resources devoted to the creation of intangibles are not simply intermediate inputs, gone by the end of one period, but should be capitalised and reap returns in additional periods; in other words they are a form of investment (Hulten, 1979).

It is impossible to get too far in the estimation process without providing some definition of what intangible assets comprise. Clearly, by their very nature they are difficult to identify, however, intangible assets have been a recognised component of the production process for a good many years: Veblen makes reference to them as early as 1908 and defines intangible assets as 'immaterial items of wealth, immaterial facts owned, valued and capitalised on an appraisement of the gain to be derived from their possession' (our emphasis, Veblen, 1908, p.105). However, intangible assets are difficult to identify, trade and indeed see.

The scope of intangibles has increased considerably in recent years which Lev (2001) argues has been driven by a variety of economic factors, including globalisation, deregulation and technological innovation, which has forced firms to innovate if they are to be profitable. Corrado et al (2009) have argued that products and services are becoming more knowledge intensive. Others however have pointed out that it is important not to conflate the growth in the post industrial economy with the increased demand for knowledge assets (Thompson et al, 2001) since much of the employment growth has been relatively low skilled growth (e.g. the growth in the retail sector). With respect to intangible assets, however, there is a general acceptance that they include a strong knowledge component which is difficult to measure in a market context because it may be tacit, and may be learned on the job. This component is growing (see e.g. Marrano et al., 2009).

Given its wide reaching but poorly defined nature, there is a danger that the term is too broad to be truly meaningful. A recent World Bank publication (2006) uses the term as a catch-all for human capital, skills, know-how of the workforce, social capital and the level of trust in the institutional framework (Roth and Thum, 2010). Blair and Wallman (2001) identify three categories of intangible assets, each progressively more difficult to measure:

(1) Assets that can be owned and sold
(2) Assets that can be controlled by the firm but which cannot be separated and sold
(3) Assets that are not wholly controlled by the firm.

This categorisation highlights the measurement problems that are likely to be encountered in the construction of intangible capital.

The existing literature offers a variety of definitions which often incorporate R&D, advertising and software measures; however, it is clear that recent attempts to define intangibles (Corrado et al, 2006; Marrano et al, 2009) agree broadly on three main sources of intangible capital.

1. Digitized information

This is measured as IT capital, composed of software as well as databases. This proportion of intangibles has been partly incorporated in the US national accounts since 1993, and more recently in the national accounts of EU countries.[1] National accounts estimates, and especially digitised information on its own, are likely to be a relatively small component of a 'true' measure of total intangibles. According to Corrado, Hulten and Sichel (2009) IT accounted for less than 15 per cent of total intangible investment over their period of study (1973-2003). Recently, there has been a reclassification of these assets in the national accounts as 'intellectual property products' (Hill, 2009), which perhaps conveys a better appreciation of what these assets are, albeit only a small part of total intangibles.

[1] Current national accounts conventions include intangibles such as computer software, mineral exploration, and artistic and literary originals (Hill, 2009).

2. Innovative Property

Traditionally composed of scientific R&D, it increasingly incorporates non-scientific R&D. By which we mean R&D in the social sciences and humanities, mineral exploration, new motion picture films and other forms of entertainment, new architectural and engineering design and new product development in financial industries. This is particularly important with the continued growth of the service sector. A number of empirical studies have incorporated R&D spend into production function estimates (e.g. Griffith et al, 2004), but often these studies do not capitalise the expenditure, as indeed an investment should be.

3. Economic Competences

Defined by Corrado et al (2006, p.28) as "the value of brand names and other knowledge embedded in firm specific human and structural resources". These include advertising and marketing expenditures; market research. This category also includes firm specific resources, including human capital (investments in training) and organizational structure (management). We refer to this subset of intangibles as organisational assets.

The first two categories are widely recognised as intangible assets, but the third category broadly incorporates expenditures on marketing and managing. This component is perhaps most difficult to measure. Empirical studies so far suggest that the contribution of this asset to productivity growth outweighs the others combined (Corrado et al, 2006).

## 2.2 Existing measures of intangible assets

**Intangibles have been estimated in a number of ways. These range from estimating the difference between the market and book values of a company to identifying variables that may be considered asset flows and then capitalising these, such as R&D expenditure and firm spending on sales, general and administrative expenses. At the macro level, this has been a means to adjusting estimates of national accounting, which underestimate economic output. At the micro level, analysts have been interested in what causes the large and persistent differences between firms. Until recently however, much of the micro work has not treated expenditure on intangibles as an investment.**

Even with broad agreement on the definition of what constitutes an intangible asset, the problem then arises of how to capture it when many of the components of intangibles do not operate within markets. A number of approaches have been taken. At the firm level, some researchers use the efficient market hypothesis (EMH) from finance theory to argue that the difference between market value (the EMH suggests market value represents the true value of the firm) and tangible assets (Tobin's-q) is a reasonable approximation of the intangible assets of a firm (Sichel, 2008; Corrado et al, 2009). Whilst informative, it fails to identify factors that contribute to intangible assets and therefore we are not necessarily closer to understanding how to foster its growth in order to raise firm performance.

Overall, the importance of intangible assets is thought to be substantial and growing. Corrado et al. (2006) estimated that the exclusion of intangible investments from measures of capital stock in the US resulted in an underestimation of US capital stock of around $3 trillion (2003 data). Using a wide ranging definition of intangibles, World Bank estimates (2006) put global intangible capital at almost 80 per cent of the World's wealth. Spending on intangibles is thought to range from 7.5 per cent of GDP in Japan 1992-2002 (Fukao et al, 2007) to around 12.1 per cent in the US in 2003. Cross country estimates for European countries (Carrado et al., 2009b) are slightly lower, with Spain and Italy having around 5.2 per cent of their GDP as expenditure on intangible assets (see Table in Roth and Thum (2010) for full details). Indeed, estimates for the ratio of adjusted (for intangible investment) to unadjusted GVA (existing national accounts) figures for the UK and the US (Table 2.1) offer considerable insight into the importance of intangibles and indicate that this importance is growing.

**Table 2.1: Ratio of GVA adjusted for intangible investment GVA unadjusted**

| Period covered | US | UK |
|---|---|---|
| **1970-1979** | 1.06 | |
| **1970** | | 1.06 |
| **2000-2003** | 1.12 | |
| **2006** | | 1.15 |

*Source: Corrado et al, 2006 for US estimates and Marrano et al, 2009 for UK estimates.*

There are a number of microeconomic studies that estimate the contribution of a subset of intangible capital, specifically organisational capital. Lev and Radhakrishnan (2003; 2005) proxy for the organisational capital by using company accounts data on Sales, General and Administrative expenses (SGA). Lev and Radhakrishnan (2005, p5) argue that organisational capital is 'an agglomeration of technologies' and that SGA represents expenditure on most of the cost items related to organisational capital, such as training, advertising and IT. Black and Lynch (2005) define organisational capital as comprising of three components; workforce training, employee voice and work design. Workforce training undertaken by firms is a relatively straightforward component, employee voice and work design relate much more to human resource management practices. Employee voice relates to the extent to which the employee has scope to contribute to management discussions and submit ideas on how to improve the production process. The last category, work design, relates to systems such as Total Quality Management and other high performance management practices.

In their analysis of US manufacturing firms, Black and Lynch (2005) emphasise the links between these components and their interaction with human capital directly. They argue that there are substantial synergies amongst workplace practices that can lead to an even greater improvement in performance. Black and Lynch (2005) utilise wage data on the basis that there is a wage premium to employment with a higher degree of organisational capital. In the UK and France, Caroli and van Reenen (2001) carried out a comparison of the impact of workplace organisation and skill demand. As discussed in Black and Lynch (2005), others have found a significant and positive relationship between earnings and organisational capital (Bailey et al 2001). Thus, the intangible investment may be embedded in the wage.

Piekkola (2009), Görzig et al. (2011), and Riley and Robinson (2011a) measure firm specific intangible capital by identifying three groups of workers that are instrumental in determining intangible assets within a firm (discussed in detail below). Organisation capital incorporates highly skilled management and marketing workers but in which we would also include social scientists. Research and development is the second category of workers which would incorporate all science based research, including architects and some medical professionals. The final occupational category of worker is IT personnel. Whilst previous growth studies have looked to incorporate a measure of IT and R&D into their production function, the measure of economic competences, captured by organization workers is a relatively new addition to the literature.

## 2.3 Human capital and intangible capital

**Whilst knowledge based, intangibles are not simply human capital measured differently. Human capital is embedded in the individual and is easily transferable. There are complementarities between these two knowledge based inputs and disentangling labour quality from intangible inputs is not straightforward.**

Human capital is an important factor of production, defined as “the knowledge, skills and competences and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD, 2001). It is clearly apparent that there are potentially overlaps between intangible and human capital. There have been attempts to measure the economic importance of human capital at an international level (OECD, 2001). These have been motivated by the fact that human capital is a recognised driver of growth. Jones and Chiripanhira (2010) have most recently applied the OECD standard approach to estimating human capital stock, defined in terms of educational attainment. They estimate this to be around £16.7bn in 2009, which they state is 2.5 times the estimated net worth of the UK over the same period. In their paper, they distinguish between *individual* human capital and *collective* human capital. The latter is more consistent with the notion of intangible assets employed here since it comprises, "work organisation, work processes, information networks and other forms of intangible, non-visible knowledge which is embedded in a group rather than individuals", (Jones and Chiripanhira, 2010, p37). This is excluded from their measure.

Thus, the quality of the workforce is a key determinant of business performance and is particularly important with respect to economic competences, but this is also true in relation to the other components of intangibles, where knowledge is also important. Labour quality is best captured by a measure of human capital which incorporates experience, training and qualifications. Black and Lynch (2001) demonstrated the importance of workplace practices as well as human capital in determining productivity. Within the human capital framework, there are two sources of intangibles. The first is training with respect to all workers, much of which may be firm specific (Black and Lynch, 2005). Secondly, there is human resource management: changes to management practices etc. It is also worth mentioning the complementarity between intangible and non-intangible workers. A higher proportion of intangible capital within a firm is likely to raise the productivity of other workers.

From the firm perspective, Bloom et al (2010) focus on management (and the quality of it) as being a crucial part of the definition of what constitutes a firm. Kaldor (1934) argued that management is the one thing that firms generally cannot have two of: a point of fixity in the definition of a firm. At the same time, management and specifically management quality is not something that features within a production function, separate from other labour input. Bloom et al (2007) review the existing evidence of the role that organizational factors play in accounting for productivity dispersion within sectors and between countries. Again, they perceive there to be a measurement error in the production function where organizational factors are not adequately taken into account. Their review concentrates on management quality and decentralization within the firm. Citing the lack of usable data for such analysis, they are able to draw some conclusions from recent empirical analysis using a specially constructed dataset of management practice in the US, UK, France and Germany. They find that firms with ‘better’ management practices perform better, across a range of performance indicators (productivity, profitability, survival, growth). Despite this, they note the persistence of a long tail of poorly performing firms. These are able to survive because of low product market competition, and in part where family run businesses persist (UK and France).

At the aggregate level Roth and Thum (2010) use a specially constructed European dataset (Jona-Lasinio and Iommi, 2010) to analyse the individual contributions of the various economic competences on economic growth. They consider three; brand names, firm specific human capital and organisational capital. The distinction between human capital and organisational capital is at first not clear cut. However, the latter category specifically relates to the management and organisational competences embedded within the firm and are largely untradeable, while the former, the general quality of workers, can move from workplace to workplace. This is measured directly through estimates of worker education and years of experience.

## 2.4 Intangibles and economic growth

**The various macroeconomic studies reveal that intangibles make a positive contribution to total GDP and indeed to labour productivity growth in general, but this varies by country. Growth accounting suggests a negative impact on the unexplained total factor productivity (TFP) component and increased capital deepening as our knowledge of what determines productivity growth improves.**

As well as the association that intangibles have with productivity, an alternative measure of performance is growth. Productivity growth is a more dynamic measure of efficiency than levels; whilst levels capture the ratio of outputs for given inputs (output per head, for example), productivity growth is concerned with the rate at which output is changing given changes in inputs. In this section, we review the more industry and nationally focussed studies of the impact of intangibles on productivity performance, the bulk of which use a growth accounting approach.

As previously stated, the traditional construction of national accounts based on value added excludes expenditures on intangibles, and therefore, when GDP is derived, they are netted out, being treated as simply an output from another sector within the economy. In reality, intangible assets are not simply outputs from other sectors which are ‘consumed’ by firms in the one time period, but have future benefits to firms and should therefore be capitalised and included in the measure of value added also. Corrado, et al are credited with developing the most commonly used methodology on incorporating a wider definition of intangibles into the national accounts methodology and have also demonstrated their contribution to productivity growth.

In a series of papers, Corrado et al (2006; 2009) take Hulten's (1979) broad definition of what constitutes an investment as being any use of resources that reduces consumption in the present period to increase future consumption. Intangibles have a number of attributes that make them unwieldy within an investment framework. They are not easily verifiable, are not always visible, may be non-rival in consumption (and thus display elements of public good) and (as with R&D) it is not always easy to fully appropriate the returns.

Having constructed intangible capital stocks, Corrado et al. undertake two exercises. First, they estimate the amount of GDP that this mis-measurement ignores, calculating national accounts with and without their measure of intangible investment. In a second stage/paper (Corrado et al, 2009), they conduct a growth accounting exercise to estimate the impact that intangibles have on the decomposition of labour productivity growth (this type of approach is discussed in greater detail in section 5.1). Their analysis highlights that excluding intangibles results in the mis-measurement of labour productivity growth. Also, within the standard growth accounting decomposition, labour productivity growth due to capital deepening (i.e. the role that capital plays in raising labour productivity growth) increases as intangibles are incorporated.

Thus we see a reallocation amongst the sources of growth. Intangibles are estimated to account for around 26 per cent of the growth changes, on a par with the size of the tangible capital component. Also, they find the labour share of value added decreases, as intangible investment is incorporated into the accounts, and displays a downward trend over time. Total factor productivity (TFP), the residual measure of 'efficiency' not explained by inputs, falls as the explanation of the determinants of growth improves. Interestingly however, they do not find that the inclusion of intermediates as a new capital input alters the acceleration in labour productivity that the US experienced in the mid 1990s, thus in and of itself, it is not the 'source' of the productivity miracle.

Marrano et al (2009) adopted a largely similar approach for the UK national accounts, constructing a measure of intangibles for the UK over the period 1990-2004. Their analysis builds on the earlier work of Basu et al (2004) and Oulton and Srinivasan (2003) which identifies that the missing expected productivity rise from IT investment is because it is not there or because it is being mis-measured. In light of the substantial investment in IT goods and services, the former seems least likely. Their analysis is on the whole not overly successful in identifying the source of the missing productivity, despite incorporating software into output, refining the measure of capital (services), and building labour quality into the labour input. The authors speculate that unmeasured organisational capital was largely the missing input.

Marrano et al (2009) draw comparisons to Corrado et al. (2009) and compare their findings as part of their robustness checks on the validity of their estimates. They find that, similarly to the US, nominal business investment in intangible assets has grown over the period, increasing from around six per cent in 1970 to around 15 per cent in 2004. Intangible investments are estimated to be roughly equivalent in value to tangible investments and they assert that around half of intangibles are derived from economic competences. Broadly, their findings mirror those in the US (albeit, to a lesser extent) except in the fact that the slowdown in labour productivity growth in the mid 1990s is largely accounted for by the exclusion of intangibles from national accounts. Both papers, Corrado et al (2009) and Marrano et al (2009) acknowledge that their measure of economic competences is far from perfect but nonetheless, their research contributes significantly to the debate.

Jona-Lasinio and Iommi (2010) explore the impact of intangible capital using a specially constructed, harmonised EU dataset that covers 27 EU countries. Linking into EUKLEMS and deriving data from national accounts sources, they find that new intangibles account for around a 0.15 percentage point contribution to annual labour productivity growth (1995-2005), although the spread across EU countries is substantial. Sweden and Greece experience negative contributions to growth 1995-2005[2], whilst new member states such as the Slovak Republic, the Czech Republic and Hungary experience substantially higher contributions from new intangible assets (around 0.25 per cent). Overall, Jona-Lasinio and Iommi conclude that the capitalisation of new intangible assets has a positive impact on labour productivity growth, but a negative impact on TFP growth (which is to be expected if we are now explaining part of the unexplained TFP residual). Generally, they note that the composition of the sources of growth (labour productivity growth, capital deepening or TFP growth) is affected by the inclusion of new intangible assets. Capital deepening in particular increases. This is consistent with the findings of other macro studies but covers a much wider range of countries.

[2] Contributions to productivity growth are calculated as the share of the input in value added multiplied by the growth in input. A negative contribution is therefore driven by a negative growth in the input.

## 2.5 Evidence of intangibles affecting firm performance

**Microeconomic studies have generally not constructed stocks of intangibles but employed intangible proxies such as R&D expenditure, management quality or the gap between company book and market value. Overall intangibles are found to have a positive effect on firm performance.**

The purpose in improving the measurement of inputs into the production process is to gain a better grasp of the determinants of performance. Understanding the various contributions that inputs make to production can help in targeting policies and efforts when looking to encourage improved performance. Therefore, we need to consider not only their contribution in terms of national accounting (as in Corrado et al, 2009), but also what they contribute in terms of improved economic performance. By and large, the macro studies to date that have focussed on intangibles and their contribution to economic growth have adopted a growth accounting approach to estimation.

There has been considerable interest in intangibles in terms of firm valuation. Hulten and Hao (2008) use US Computstat company accounts data for 2006 to explore how far intangible capital explains the discrepancy between market and book value (the value of the sum of shares compared with the sum of assets) of a company (Tobin's q). Using the Corrado et al (2006) approach to estimate intangible capital (as far as Compustat data allow), they find that they are able to explain 75 per cent of equity when intangibles are added to the book value, compared with only 31 per cent without them. Thus, current accounting practices consistently understate the long run value of companies. Other explanations Hulten and Hao (2008) put forward for the remaining gap include stock market volatility and the Schumpeterian gap between assumed returns to innovation and actual returns. They also acknowledge other measurement problems in the balance sheet, but the overall importance of intangibles is stark.

Whilst considerable efforts have been directed to the role that R&D plays in productivity, empirical evidence exploring the impact of intangible capital on other performance indicators beyond R&D is less common. Megna and Mueller (1991) is an early notable exception which explores the impact of intangibles (defined as R&D and advertising expenditure) on US firms' profits. They use COMPUSTAT company accounts data for their analysis for the period 1967-1988 (so prior to the IT/knowledge economy boom). Their analysis constructs firm level intangible capital stocks using these expenditures (investments) on R&D and advertising. They consider not only own firm, but also (to allow for spillovers) rivals' expenditure on R&D and advertising. They estimate a profit function, where after tax profits are a function of own advertising capital, rivals advertising capital, R&D capital, rivals R&D capital and physical capital. They focus on only four US sectors, to ensure that the R&D and advertising expenditures are large enough. In addition firms needed to be relatively non-diverse, and crucially, firms could only be included if there was a reasonable time series available. They estimated their econometric equation for only 28 US firms.

Whilst they find significant differences in returns to intangible capital across firms, they maintain that differences in profitability are not simply addressed by adjusting profitability to take account of differences in intangible capital. However, Megna and Mueller (1991) is somewhat dated now, evidenced by the very narrow definition of intangibles compared to those in more recent studies.

## 2.6 Spillovers to intangible capital

**Intangible assets are also thought to lead to indirect benefits through spillovers at a regional level. New evidence on this suggests that intangibles account for a significant proportion of agglomeration economies, although not all.**

Because of the tacit nature of intangible capital the benefits are unlikely to be fully appropriated by the firm that makes the investment (Geppert and Neumann, 2010) and are likely to benefit others as an externality. Spillovers, or positive externalities, are traditionally thought to occur either within a region, within a supply chain or within an industry (Harris and Robinson, 2002) and are closely associated with skilled workers and innovation. Given the importance of intangibles to innovation and the role that knowledge plays in intangible assets, it seems highly likely that spillovers from intangible assets will take place.

At the sectoral level in the UK, Artis et al (2009) use patent data as a measure of innovation in their study of agglomeration economies in Great Britain and their impact on productivity performance at a regional level. Their point of departure is Ciccone (2002) and using local area data (NUTS3) they construct a variety of indicators to capture intangibles and model their effect on GVA per job filled at the regional level. They find a significant effect of agglomeration economies on productivity which diminishes slightly when the more intangible assets are taken into account and even more so when account is taken of the spatial autocorrelation, that is, the extent to which variables (GVA per job filled) display geographical interdependencies. However, agglomeration economies are still significant.

In a recent paper that examines the role of intangibles within a regional context using firm level data, Geppert and Neumann (2010) find that in Germany, intangible capital is highly regionally concentrated, suggesting agglomeration economies to intangible capital. This is a well documented phenomenon within the R&D literature. However, in their cross sectional study of wage rates (their proxy for productivity) in establishments, they find that a doubling of intangible capital intensity of establishments would increase wages by about one per cent, but that tangible capital is still more influential. They also identify a positive externality from intangible workers to non-intangible worker within establishments. Adopting a similar approach, Riley and Robinson (2011b) find evidence of a positive association between regional (City Region) intangible capital intensity and UK firms' productivity. The measures of intangible capital in these studies are constructed in much the same way as the approach used in this report, subject to data differences, sector and size coverage. In general, this is an area where there is scope for further research.

## 2.7 Summary

The increased importance of intangible assets, as the definition has broadened beyond R&D, has sprung from technological advances in information and communication, shifts in industrial structure and changes to workplace practices and organisation. As these assets have become more important, and with increasing evidence of persistent heterogeneity amongst firms, it has become apparent that the standard production function and sources of growth models need to be adapted to incorporate these additional inputs. However, the first step is measuring intangibles and then recognising that they are often not purely intermediate goods, but have at least a component that must be regarded as an investment, and therefore capitalised. In constructing measures of intangible assets, which rarely fully operate within open markets, a reoccurring theme is the importance of the knowledge component and therefore it is difficult to disentangle increased demand for skills from the growth in intangible assets. This is particularly true with regards to a firm's economic competencies, their organisational capital. Existing studies at the macro and the micro level estimate intangible assets to be highly significant, not only in their contribution to growth but also in challenging our understanding of the sources of growth.

This review has tried to bring together theory and evidence, of both macro and micro economic approaches to the measurement of intangibles and their incorporation into the production process. As well as looking at intangibles as inputs, we explore the impact that they have on outputs, through growth, productivity and other indicators of performance. We now go on to discuss the way in which our data are constructed and how they will contribute to the existing knowledge base.

# 3. Measures of firm level intangibles for the UK

**Measures of intangible capital are constructed from occupational wage and employment data for UK firms. In this Chapter we provide details of data sources and the methodology used to construct the data.**

Given the substantial knowledge component of intangible capital we use occupational information at the firm level to construct intangible assets. The dataset constructed here builds on earlier work on a harmonised dataset of intangible assets across a number of European Countries (Görzig et al., 2011). We begin by discussing the sources of firm level data for the UK and measurement and then go on to detail how our occupationally defined measure of intangible assets has been constructed. Our measure of intangible assets focuses exclusively on the intangible assets produced within the firm (using employees), rather than those purchased from the marketplace. The distinction between own account and purchased intangibles is not always clear, but attempts to measure own account intangibles within the large national studies suggests that these internal intangibles account for nearly half the overall measure (Haskel et al., 2011).

It is worth highlighting a number of extensions to our initial UK dataset, described in Riley and Robinson (2011a). Firstly, we have increased the coverage of the data to include all firms[3]. We believe small firms are a major source of employment opportunities within the UK economy and should therefore feature in our UK dataset. Another extension has been to change the sector coverage from that used in the European harmonised dataset. We provide greater detail on this below, but broadly our dataset covers around 40 of the 2-digit NACE (rev 1). In this Chapter we provide a discussion of how the data have been constructed and then go on to present some emerging trends from our disaggregation of occupational groups of relevance to intangible capital in UK firms.

## 3.1 Data sources

**The Annual Survey of Hours and Earnings and the Labour Force Survey are the sources of individual occupation and wage data. These are combined with firm level data from the Business Structure Database and the Annual Business Inquiry to construct employee and employer data for the period 1998-2006.**

[3] The earlier data included only those with 30 or more employees.

The data sources that have been used to construct our measure of intangible assets are an exhaustive collection of UK data and include the Annual Survey of Hours and Earnings (ASHE) and the Labour Force Survey (LFS). These surveys contain detailed information on occupations and earnings for a sample of individuals in the UK. Our data on individuals have been linked to business surveys held by the ONS at the Virtual Microdata Laboratory. The business datasets that we have to link to, are the Annual Business Inquiry (ABI or ARD) and the Business Structure Database. The latter contains very basic information on all UK registered firms (based on VAT and PAYE registers). The former contains a sample of UK firms (a census of large firms) with detailed financial information.

The data cover the period 1998-2006. This is a period of increasing investment in IT technologies. To construct occupationally based measures of intangibles for UK firms we link employee-level data in the ASHE to firms in the ARD via a detailed industry and firm size matrix. It is also possible to link the employee-level data to firms via the firm identifier, but this is only meaningful for large firms with enough workers represented in the ASHE (the ASHE samples around one per cent of workers and therefore only a very small number of workers are available for each firm). Riley and Robinson (2011a) assess differences in the intangibles data for large firms arising due to different linking methods. Differences are largest for organisational investment, and smaller for R&D and IT investment.

## 3.2 Occupational classification

**UK SOC codes are used to allocate workers to IT, R&D and Organisation categories of intangible assets. In this section we justify the choice of occupations and provide an overview of the importance of these occupations within each intangible category. We emphasise also that the occupational classification changes over time, meaning that intangibles data prior to 2002 and from 2002 onwards are not directly comparable.**

In order to begin our construction of intangible capital stock, we assess the numbers and the wages of intangible workers, defined in accordance with the emerging literature on intangibles.

(1) R&D workers
(2) IT workers
(3) Economic competences, composed of managers and marketing workers

We identify workers on the basis of their principal occupation given in the ASHE (and then link to firms on the basis of the firm size-sector matrix, discussed below). The full list of occupations assigned to each category and their corresponding SOC code is provided in Table A1 in the Appendix.

***The occupational definition of intangible assets***

In defining intangible assets, we recognise that any choice of definition is open to question. Our approach has been relatively inclusive and is consistent with recent work carried out for the European Commission. The harmonious approach taken there allows for meaningful comparisons to be made across countries. We take care to ensure that occupations are allocated to intangible asset categories that broadly reflect the definitions of intangible capital used in the existing literature.

Our starting point is the work by Corrado et al (2006; 2009), which we discuss in Chapter 2, where three components are identified as defining intangible assets; R&D, IT and economic competencies. They correspond to R&D workers, in the broadest sense, IT workers and organisation workers. We translate occupations into these categories in a harmonised way across countries by adopting the ISCO88 occupational coding and mapping these to the UK occupational classification (SOC2000 and SOC90).

Clearly any mapping has the odd idiosyncrasy and care has been taken to iron out a number of them. It is worth emphasising that we deliberately define R&D in a much broader sense than generally used in the literature, which tended to be limited to production and manufacturing R&D. This is particularly important given the relative size of the service sector now which would, with a conventional definition, underestimate R&D assets. Certain scientific (dental and vet) professionals are classified within R&D because of their tendency to participate in the academic advancement of their profession.

For organisation workers, the allocation to intangible workers is a little more complicated. Some occupations were included only when they were based in certain industries or in firms that were above a certain size. For example, we assume musicians, artists, and choreographers are likely to be involved with some marketing or brand equity enhancing activity when employed in the production sector. Hence these are classified as intangible workers when observed in production (occupations shaded in green in Appendix Table A.1).

Before we discuss our data in more detail, we use the UK Labour Force Survey for 2006 to illustrate the percentage share of particular occupations in all intangible occupations. These are shown in Appendix Table A.1. The LFS data accord with the overall shares observed in our data (constructed from the ASHE and presented in the following sections). However whilst providing a useful check on our ASHE based calculations, this analysis demonstrates which occupations dominate our intangible categories. Table 3.1 confirms the overall shares for 2006. R&D share of total occupations is 5.2 per cent, slightly higher than in the ASHE data. IT occupations 3.0 per cent, consistent with our estimates, and organisational occupations, 5.79 per cent and 4.27 per cent, combined. We split organisational occupations because there are a number of occupations that are only included for larger firms (greater than 10 employees), such as hairdressing managers, for example. Whilst we discuss the rationale for this above, it is useful to explore the magnitude. It is interesting to note that the combined share is consistent with our estimates, presented in Figure 3.2, of around 10 per cent.

**Table 3.1: Occupational group shares (aggregates) from the Labour Force Survey**[4]

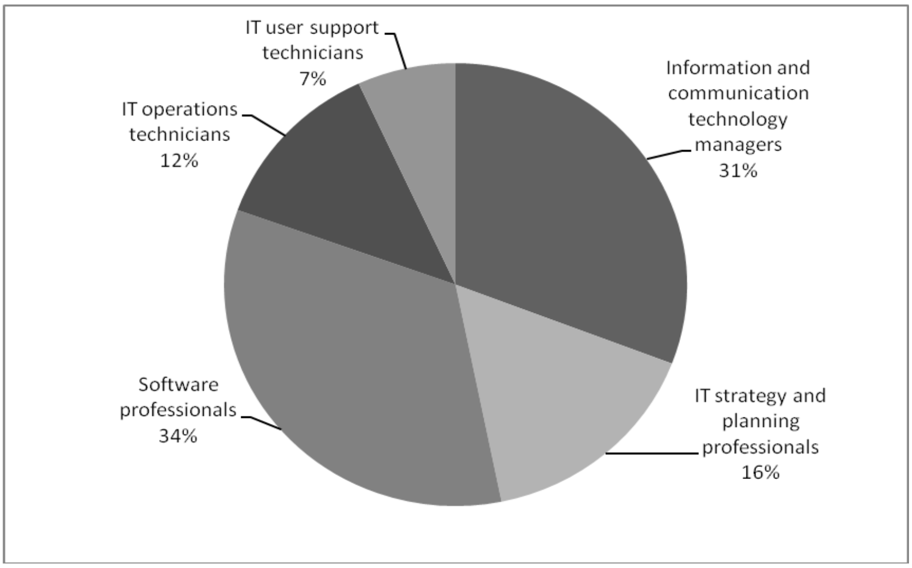
| Occupational Groups | Weighted numbers | Percentage |
|---|---:|---:|
| | | |
| Other occupations | 18,964,675 | 81.68 |
| R&D occupations | 1,214,268 | 5.23 |
| IT occupations | 701,504 | 3.02 |
| Main Organisation occupations | 1,344,937 | 5.79 |
| Organisation for large firms only | 991,910 | 4.27 |
| | | |
| Total | 23,217,294 | 100 |

*Source: Quarterly LFS 2006, wave 1 only; note: we exclude 2 digit sectors 01, 02, 05 as well as 65, 66, 67 and 95, 99.*

The shares of occupations within each intangible category are presented in Appendix Table A.1. In summary, we note that for R&D occupations, medical practitioners account for 14.25 per cent of all R&D occupations. Given that these are largely located in sector N, Health and Social work, these are unlikely to be included in our market sector analysis, because of problems with quantifying outputs and measuring tangible capital stocks. Other occupations which are important in R&D include engineering professionals and biological scientists, which account for a combined share of around 10 per cent. All other occupations (totalling 33), generally account for between 0.5 and four per cent each. IT occupation shares are presented in Figure 3.1. Note that IT user support technicians account for the smallest share of workers in IT occupations, around 6.5 per cent. IT managers and software professionals account for the largest shares.

[4] We gratefully acknowledge the Data Archive for granting access to the LFS data.

**Figure 3.1: IT occupational composition, 2006**




*Source: LFS, 2006, own calculations.*

In the case of organisation worker shares, again, the number of categories makes it difficult to present graphically (22 categories). Full details are presented in Appendix Table A.1. In summary, we note that for the main organisation grouping, marketing and sales managers account for around 29 per cent of the total, with financial managers accounting for a further 10 per cent. These are financial managers not working within the financial sectors (SIC65-67). It is perhaps worth emphasising that actors and musicians, that were included in this category subject to being in production or transport sectors, account for less than 0.2 per cent of the total. Turning to the occupations included in the organisational worker category if they are employed in larger firms only, we note that of the 23 occupations, production works and maintenance managers, managers in construction and retail and wholesale managers combined account for around 53 per cent of all workers in this subsection. All other occupations account for between 0.3 and six per cent of the subgroup total.

Our choice of intangible workers was also informed by our understanding of the way in which skills are employed in the economy. Table 3.2 presents the overall skills profile of intangible workers and it is evident from this table that the intangible occupations are dominated by highly qualified workers. Amongst R&D workers, A-level or above qualifications are held by more than 86 per cent of the occupation group; almost double that in the 'other' occupation category. IT workers are similarly qualified (78 per cent) as are organisation workers, with around 73 per cent of the occupational group having post compulsory education. Conversely, in these occupation categories, those with no qualifications make up a much smaller proportion of workers accounting for less than five per cent, compared to almost 15 percent amongst the 'other occupation' category. This, coupled with the data we have from

ASHE on average earnings of other occupations, clearly illustrates that higher skilled workers are concentrated in the occupations that we define as intangible occupations.

Notwithstanding these justifications and the relatively modest shares that appear to relate to the potentially more contentious occupations, ultimately our choice of occupations is based on simple judgement. It is worth making the point that only a proportion of these workers' time is allocated to investment. This also means that only a small proportion of organisational workers' time in particular, is regarded as being investment into future income streams. We go through the various assumptions made in the construction of capital stocks in the following section.

Finally, another important issue that affects our approach is that the early occupational classification in the UK, SOC90 classification, tended to overstate the management occupational group. In subsequent refinements and matching to ISCO88, managers are more closely defined by using firm size bands. Therefore, for those occupations shaded pink in our appendix Table, these workers are only classified as intangible workers if they are employed in firms with at least 10 employees. These occupations are labelled as managers, but, in order to be classified as intangible workers we require the firm to have a sufficient number of workers, e.g. hotel and accommodation managers or garage managers and proprietors.

**Table 3.2: Percentage share of the highest qualification obtained by occupational group, 2006.**

| | Degree or equivalent | Higher education | GCE A- level or equivalent | GCSE grades a-c or equivalent | Other qualifications | No qualifications | Don't know | Total |
|---|---|---|---|---|---|---|---|---|
| R&D occupations | 55.37 | 14.89 | 16.11 | 6.16 | 4.30 | 2.22 | 0.95 | 100.00 |
| IT occupations | 50.23 | 12.03 | 16.16 | 12.55 | 7.17 | 1.48 | 0.38 | 100.00 |
| Organisation occupations | 41.37 | 11.71 | 19.87 | 14.81 | 6.80 | 4.41 | 1.03 | 100.00 |
| Other occupations | 15.64 | 8.27 | 23.34 | 23.39 | 13.38 | 14.61 | 1.36 | 100.00 |
| | | | | | | | | |
| **Total** | **21.36** | **9.08** | **22.40** | **21.30** | **12.06** | **12.54** | **1.27** | **100.00** |

*Source: LFS 2006, wave 1; data weighted using LFS population weights.*

### *ASHE data overview*

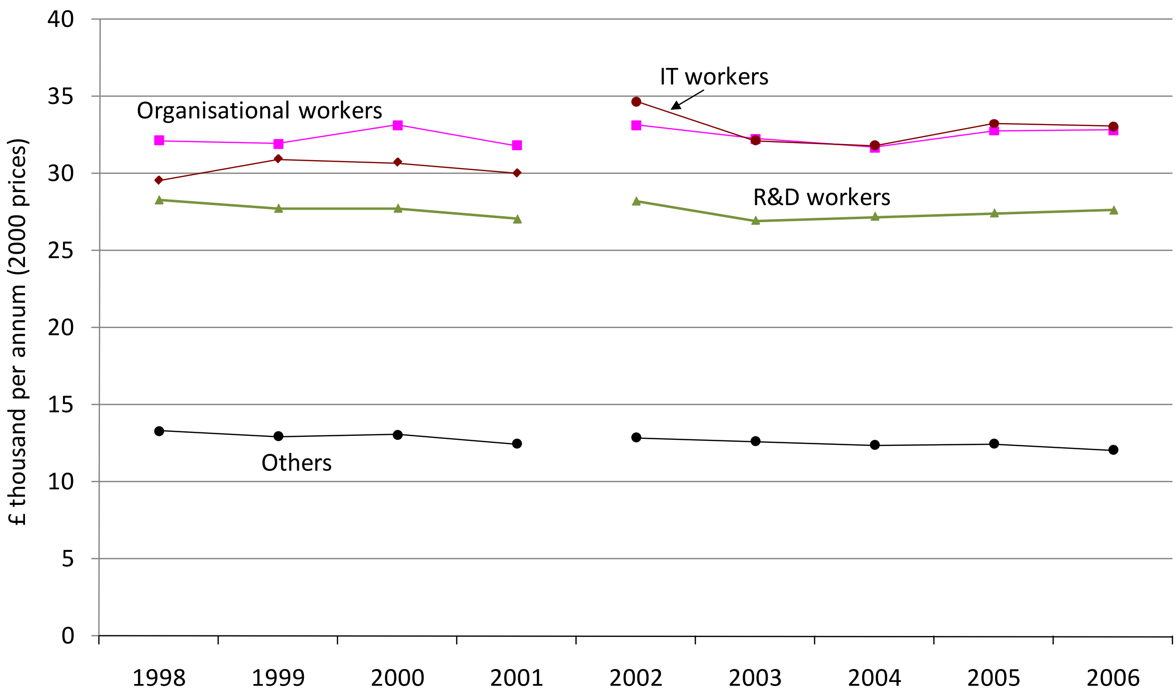
Figure 3.2 provides an overview of shares of workers in occupational groups. Due to the change in the SOC classification between 2001 and 2002 the data are not strictly comparable between the first and second parts of the sample, as indicated by the discontinuity in Figures 3.2-3.3. Nevertheless, at the aggregate level the data are not very different between the two sub-periods. Organisational workers make up over 10 per cent of the workforce; this increased by around one percentage point between 2000 and 2001. The new level is maintained in the post 2002 data but there is little or no growth. R&D workers and IT workers account for much smaller shares of total employment (less than four per cent and less than three per cent, respectively). These shares are broadly constant over time.

**Figure 3.2: Percentage share of intangible workers in the UK, all sectors*, 1998-2006**


*Source: ASHE, ABI various years, authors calculations; *excluding agriculture, financial services and public administration.*

The employment cost for each of these categories (weighted to be nationally representative) is presented in Figure 3.3. In addition to the occupational categories used in Figure 3.2, we include the employment costs of other employees as well as intangible workers, and note that earnings are substantially lower amongst this occupational category. R&D workers earn less than other intangible workers.

**Figure 3.3: Annual employment costs by occupation group, all sectors*, 1998-2006**




*Source: ASHE, ABI various years, authors calculations; *excluding agriculture, financial services and public administration.*

Whilst an interesting overview, we are also concerned with what is happening at a more disaggregated level. In the following sections we present some findings by a disaggregated sectoral breakdown. Here we simply illustrate the importance of individual sectors in terms of their share of gross value added, employment and labour productivity levels.

The firm level data constructed may be categorised by NACE (rev 1) sectors. Table 3.3 details the industries for which we have data. Note that here we are able to provide descriptive statistics on non-market sectors of health and education, however these are excluded from the econometric and growth accounting analyses because of problems associated with output measurement in the public sector. A number of other sectors need to be excluded from the econometric estimations because of little or no capital data. Table 3.3 contains basic descriptives for the widest possible number of sectors, enabling us to see the relative importance of sectoral contributions. Note for example that retail trade accounts for around 13 per cent of employment and around 8.5 per cent of GVA. In the final column, we also provide average labour productivity levels over the period 1998-2006. Note that mining and quarrying is an outlier, the result of its extremely high capital intensity, thus labour productivity is high; the same is true for electricity gas and water supply.[5] Note the high productivity in the manufacture of office machinery and computers (30) and also the manufacture of chemicals and manmade fibres (DG). Whilst labour productivity in water transport (62) is quite high, this accounts for less than 0.1 per cent of employment and less than 0.3 per cent of GVA.

**Table 3.3: Sectors included in the Intangibles database**

| NACE CODE | Description | % employment | %GVA | GVA/ hour |
|---|---|---|---|---|
| CA | Mining and quarrying of energy producing materials | 0.18 | 2.80 | 212.15 |
| CB | Mining and quarrying except energy producing material | 0.14 | 0.28 | 26.24 |
| DA | Manufacture of food products; beverages and tobacco | 2.19 | 3.26 | 21.28 |
| 17 | Manufacture of textiles | 0.55 | 0.48 | 13.01 |
| 18 | Manufacture of wearing apparel; dressing and dyeing of fur | 0.39 | 0.29 | 13.37 |
| DC | Manufacture of leather and leather products | 0.08 | 0.08 | 14.70 |
| DD | Manufacture of wood and wood products | 0.39 | 0.39 | 13.68 |
| 21 | Manufacture of pulp, paper and paper products | 0.40 | 0.56 | 19.34 |
| 22 | Publishing, printing and reproduction of recorded media | 1.60 | 2.41 | 23.29 |
| DG | Manufac. of chemicals, chemical products and man-made fibres | 1.06 | 2.55 | 36.06 |
| DH | Manufacture of rubber and plastic products | 1.03 | 1.21 | 16.71 |
| DI | Manufacture of other non-metallic mineral products | 0.58 | 0.79 | 19.15 |
| 27 | Manufacture of basic metals | 0.44 | 0.55 | 17.42 |
| 28 | Manufacture of fabricated metal products, except machinery and equipment | 1.65 | 1.86 | 15.53 |
| DK | Manufacture of machinery and equipment n.e.c. | 1.47 | 1.94 | 18.78 |
| 30 | Manufacture of office machinery and computers | 0.19 | 0.44 | 39.44 |
| 31 | Manufacture of electrical machinery and apparatus n.e.c. | 0.71 | 0.81 | 16.90 |
| 32 | Manufacture of radio, television and communication equipment and apparatus | 0.46 | 0.77 | 25.49 |
| 33 | Manufacture of medical, precision and optical instruments, watches & clocks | 0.58 | 0.84 | 21.82 |
| 34 | Manufacture of motor vehicles, trailers and semi-trailers | 0.96 | 1.36 | 20.02 |
| 35 | Manufacture of other transport equipment | 0.71 | 1.32 | 25.97 |
| 36 | Manufacture of furniture; manufacturing n.e.c. | 0.90 | 0.90 | 14.30 |
| 37 | Recycling | 0.07 | 0.10 | 18.32 |
| E | Electricity, gas and water supply | 0.58 | 2.56 | 64.74 |
| F | Construction | 5.86 | 7.04 | 16.26 |
| 50 | Sale, maintenance & repair of motor vehicles; retail sale of fuel | 2.71 | 3.32 | 17.50 |

[5] This highlights the limitations of labour productivity as a partial measure of productivity and explains why Total Factor Productivity is the conceptually preferred measure.

| | | | | |
|---|---|---|---|---|
| 51 | Wholesale trade & commission trade, except of motor vehicles & motorcycles | 5.35 | 8.53 | 23.65 |
| 52 | Retail trade, except ...; repair of personal & household goods | 13.27 | 8.47 | 12.19 |
| H | Hotels and restaurants | 8.03 | 3.76 | 8.68 |
| 60 | Land transport; transport via pipelines | 2.51 | 2.50 | 12.58 |
| 61 | Water transport | 0.08 | 0.26 | 46.74 |
| 62 | Air transport | 0.40 | 0.90 | 35.22 |
| 63 | Supporting & auxiliary transport activities; activities of travel agencies | 1.63 | 2.61 | 22.82 |
| 64 | Post and telecommunications | 2.28 | 4.86 | 30.33 |
| 71 | Renting of machinery & equipment without operator & of personal & household | 0.74 | 1.63 | 31.54 |
| 72 | Computer and related activities | 2.38 | 4.54 | 29.22 |
| 73 | Research and development | 0.42 | 0.49 | 17.69 |
| 74 | Other business activities | 13.50 | 14.84 | 18.56 |
| M | Education | 13.31 | 0.89 | 1.24 |
| N | Health and social work | 4.51 | 1.69 | 6.73 |
| 90 | Sewage and refuse disposal, sanitation and similar activities | 0.33 | 0.83 | 33.16 |
| 91 | Activities of membership organization n.e.c. | 0.91 | 0.31 | 6.27 |
| 92 | Recreational, cultural and sporting activities | 2.87 | 2.81 | 16.86 |
| 93 | Other services activities | 1.61 | 1.17 | 11.92 |

## 3.3 Measuring intangible investment and capital

**Proportions of intangible goods produced by the firm are for future use and therefore need to be treated as capital. A number of assumptions need to be made for example, about the share of goods for future consumption and starting stocks. This section explains the assumptions made in the construction of intangible investment and capital.**

We measure intangible investment and capital following the methodology adopted in INNODRIVE (European Commission FP7 project), which is described in full in Görzig et al. (2011). Here we outline briefly their methodology. Crucially, a firm’s investments in intangible assets are assumed to be proportional to the firm’s labour costs associated with workers in intangible occupations (i.e. involved in the creation of intangible capital goods). The proportionality factor is a multiple of the share of intangible workers’ time that contributes to future production and a scaling factor to account for other (non-labour) inputs associated with the production of intangible capital goods.

We assume that firms produce goods for output and also intangible goods of the three types discussed above: IT, R&D and Organisational capital (OC) goods, exclusively directed towards firms' own use. If the uses are not in the current year, these types of goods can be classified as intangible capital goods. In order to produce them, firms apply resources supplied by different factors of production: labour, intermediate, and capital services. To assess labour services that go towards the production of these intangibles, we distinguish three types of labour input: IT-, R&D-, and OC-related personnel (see Appendix Table A.1 for the SOC2000 classification).

We assume that only a fraction of workers in these occupations are engaged in the production of intangible capital goods; with the remainder of these workers engaged in current production (i.e. production of goods and services with a service life less than a year). Specifically, we assume that 50 per cent of IT workers' time, 70 per cent of R&D workers' time and 20 per cent of organisational workers' time is spent on the production of intangible capital goods (see investment share of labour in Table 3.4). To account for the capital services and materials that complement this labour in the production of intangible assets we scale the relevant labour expenditures with the ratio of total production to labour costs in the IT, R&D and Business services sectors; NACE 72, 73 and 74 respectively. These are shown as the factor multiplier in Table 3.4. The product of this factor multiplier and the investment share of labour yields the combined multiplier in Table 3.4, which is essentially the scaling factor we apply to firms' expenditures on 'intangible' workers. Intangible investment for firm *i* at time *t* is then derived as:

$$I_{ICit} = M_{IC} w_{ICit} L_{ICit} \tag{1}$$

where $IC = OC, R\&D, IT$ , $M_{IC} = h_{IC} \cdot m_{IC}$ is the combined multiplier (shown in Table 3.4), $w_{ICit}$ is the wage cost for workers engaged in the production of intangible assets (deflated by the earnings index, which is assumed to represent the deflator for intangible assets) and $L_{ICit}$ is the respective labour input of these workers.

Görzig et al. (2011) provide some rationale for the assumptions concerning the investment shares of labour and the factor multiplier used here. As in much of the intangibles literature there is relatively little basis upon which to justify many of these assumptions. Riley and Robinson (2011a) evaluate the combined multiplier within an estimated production framework. Their results suggest that on average the combined multiplier derived in this way is not very different from the combined multiplier used here (for R&D and OC capital only). Note that the intangible investment and capital stocks discussed in this report are easily adjusted to reflect alternative assumptions about the combined multiplier (scaling factor) than those listed in Table 3.4. For example, in this report investment in IT is derived as 70 per cent of the labour cost associated with IT workers (the combined multiplier is set to 0.7). To arrive at IT investment assuming instead that 80 per cent of the labour cost associated with IT workers reflects IT investment, we can scale the figures in this report by 1.14 (=0.8/0.7). Our econometric results below are robust to the choice of scaling parameter because the production function is log-linear.

**Table 3.4: INNODRIVE Assumptions**

| | IT | R&D | OC |
|---|---|---|---|
| Investment share of labour $h_{IC}$ | 0.5 | 0.7 | 0.2 |
| Factor multiplier $m_{IC}$ | 1.48 | 1.55 | 1.76 |
| Combined multiplier $M_{IC} = h_{IC} \cdot m_{IC}$ | 0.7 | 1.1 | 0.35 |
| Depreciation rate | 0.33 | 0.20 | 0.25 |

*Source: Görzig et al. (2011).*

We capitalise these investments according to the perpetual inventory model:

$$K_{ICit} = I_{ICit} + (1 - \delta_{IC}) K_{ICit-1} \quad (2)$$

with depreciation rate $\delta_{IC}$, which varies by type of asset $IC = OC, R\&D, IT$ (see Table 3.4), and gross capital formation in the current year $I_{ICt}$. $K_{ICt}$ denotes the closing stock (at the end of the year). The opening stock, $K_{ICt-1}$, is the stock a firm starts with (at the beginning of the year). Note that the depreciation rates we assume for intangible capital goods are much higher than the depreciation rates typically assumed for tangible capital; intangible assets are assumed to have relatively short service lives. For years where firms are absent from the sample investment is constructed using a simple linear interpolation. This mostly concerns SMEs (enterprises with less than 250 employees), which are not required to respond to the Annual Business Inquiry every year.

We need to assume an initial capital stock in the year before we observe a firm in the data, $K_{ICi}^{start}$. We assume constant investment growth *g* (set at two per cent per annum) in the period before we observe a firm. This means that we can that write:

$$K_{ICi}^{start} = I_{ICi}^{start} \frac{1-(1-\delta_{IC}-g)^T}{1-(1-\delta_{IC}-g)} \tag{3}$$

where $I_{ICi}^{start}$ denotes intangible investment in the year before we observe a firm, and T is set to 100. In practice we proxy $I_{ICi}^{start}$ with the sample average for firm *i* (discounted appropriately). In section 4.3 we illustrate the sensitivity of our econometric results to these starting stock assumptions.

## 3.4 Other production inputs

**As well as intangible capital, other inputs need to be constructed before productivity can be considered, particularly tangible capital construction.**

Capital is constructed as plant and machinery capital stocks[6]. This has been constructed using investment flows to firms in the ABI data. In addition, we have numbers employed and an hours work measure constructed with the aid of the ASHE data, as the ABI does not collect information on hours worked.

## 3.5 Firm level Intangibles data described

**Sector level exploration of the intangibles data reveals them to be important in a number of sectors, but particularly important in high technology sectors in both production and services. Organisation workers account for more employment and wage bill shares across all sectors. R&D and IT appear to be more sector specific.**

As part of the data construction process, it is useful to get an idea about the magnitude and indeed the variation in the occupational asset data. The following charts (Figures 3.4-3.6) show the employment and wage bill shares of workers in intangible occupations and the ratio of intangible capital to GVA. We average over two periods, 1998-2001 and 2002-2006. These periods coincide with the occupation classification change and therefore direct comparison between before and after should be exercised with caution. However, what we are able to do with these charts is to look at the relative compositions and how they vary over sector and consider the overall magnitudes of investment in intangible capital.

[6]Kindly provided to us by Professor Richard Harris, Glasgow University, CPPR. Details of the construction of capital stocks are available in Harris and Drinkwater, 2000.

From Figure 3.4a, production sectors that are particularly intangible-rich in terms of employment shares include mining and quarry of energy products (CA), the manufacture of office machinery and computers (30), radio, TV and communications equipment (32) and medical, precision and optical equipment (33). Chemicals also have high levels of overall intangibles, accounting for almost 35 per cent of employment in the 2002-2006 period. The manufacture of leather products is particularly low in terms of intangible employment shares: less than 10 per cent of employment in total. Looking at the composition, the R&D component expands in the second period, perhaps an artefact of occupational coding change. In most sectors, organisation capital is dominant, except in the highly intangible-rich sectors (c.f. 30-33) which are more evenly composed of intangible assets. IT worker shares seem to have the smallest shares of all intangibles, but these seem broadly proportionate to the overall magnitude of intangibles; those with large shares of intangible workers also have larger IT shares as a proportion of total intangibles.

Figure 3.4b looks at employment shares in construction and service sectors. Post and telecommunications (64) has a large share of intangible workers. It is perhaps worth noting that in service sectors, the role of IT workers is much more noticeable than in the production, but with the exception of sector 72, organisation workers dominate again. Outside of the R&D sector, R&D workers have a relatively small role to play.

In relation to compensation received by intangible workers presented in Figures 3.5a and b for production and services respectively, we note that in production (Figure 3.5a) the percentages are higher than for employment shares, indicating that these workers are generally higher paid than average. This seems to be most clearly true for organisation workers and perhaps least evident for R&D workers. The industry ranks do not alter noticeably. In the service sectors (Figure 3.5b) again the rate of pay received by organisation workers appears to be higher than other workers, including R&D and IT workers, whose wage bill shares seem more consistent with their employment shares. Again, sectoral patterns observed in employment shares are not dramatically changed when looking at compensation.

Figures 3.6a and b look at intangible intensity, defined as the ratio of investment in intangibles to value added, in firms by sector, firstly in production and then in services. Taking Figure 3.6a for production, we see that R&D investment accounts for a much larger proportion of value added than organisation investment. This reflects the relatively small portion of organisation workers that are used in the intangibles construction (0.35; Table 3.4) and the relatively large portion of R&D workers (1.10; Table 3.4). Fluctuations in the averages between the two periods are greater (especially observed in 30) although again, sectors in which intangible shares were highest also show highest intangibles intensity. Note that R&D (73) stands out as the sector with the largest intangibles intensity overall, as well as Computer and related activities (72). In these sectors the ratio of intangible investment to GVA approaches 60 per cent and we have excluded them from our Figures here[7]. The majority of sectors display much more modest ratios, most not exceeding 10 per cent. Some exceptions to this are post and telecommunications (64) and business services (64) and education, health and activities of membership organisations (91).

Overall therefore, these charts show that intangibles are important in most sectors but are dominant in a handful that include R&D, computers and computing related activities in terms of services and the production of chemicals, precision equipment and computers in manufacturing. This is in line with our expectations that higher technology driven sectors are likely to have higher levels of intangible assets. However, it is clear that intangible assets are not limited to these sectors. Organisation capital in particular is important across most sectors. R&D and IT are more sector specific.

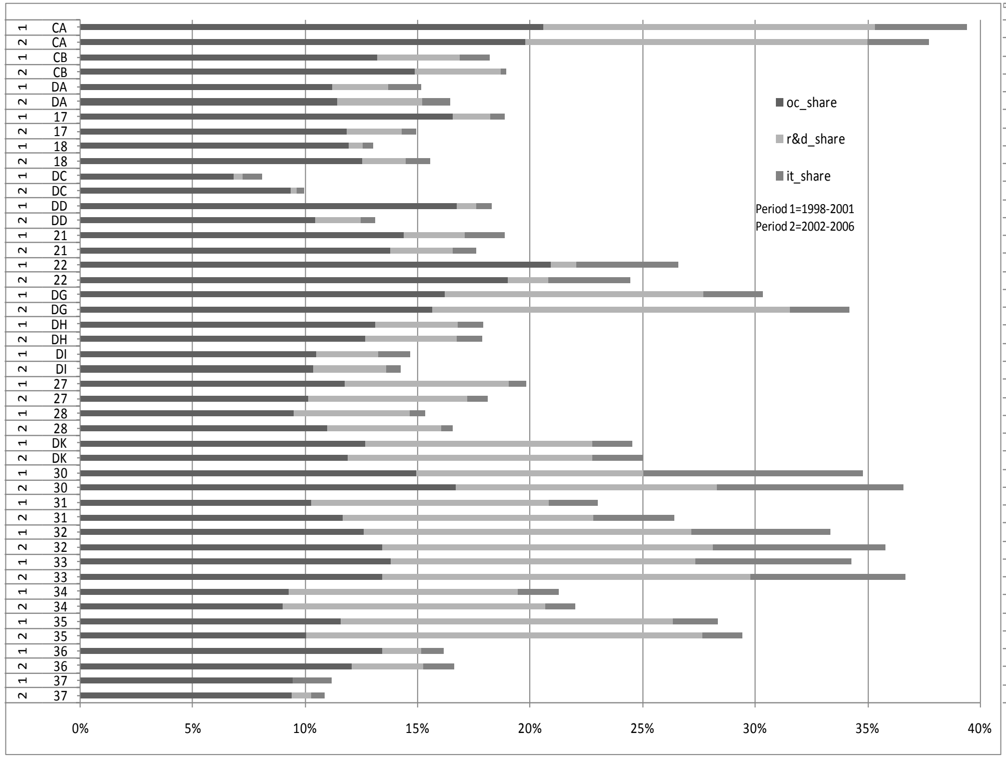
### 3.6 Summary

This Chapter has discussed the construction of the firm level intangibles database for the UK. We have used nationally representative data to construct an occupationally defined measure of intangibles and have capitalised these investment streams using standard methods and a number of assumptions regarding depreciation rates and the like. We find that the shares of intangibles in terms of employment and wages accord with our general understanding that intangibles are likely to be more prevalent in higher technology sectors, that R&D is particularly sector specific and that organisation capital is quite universal.

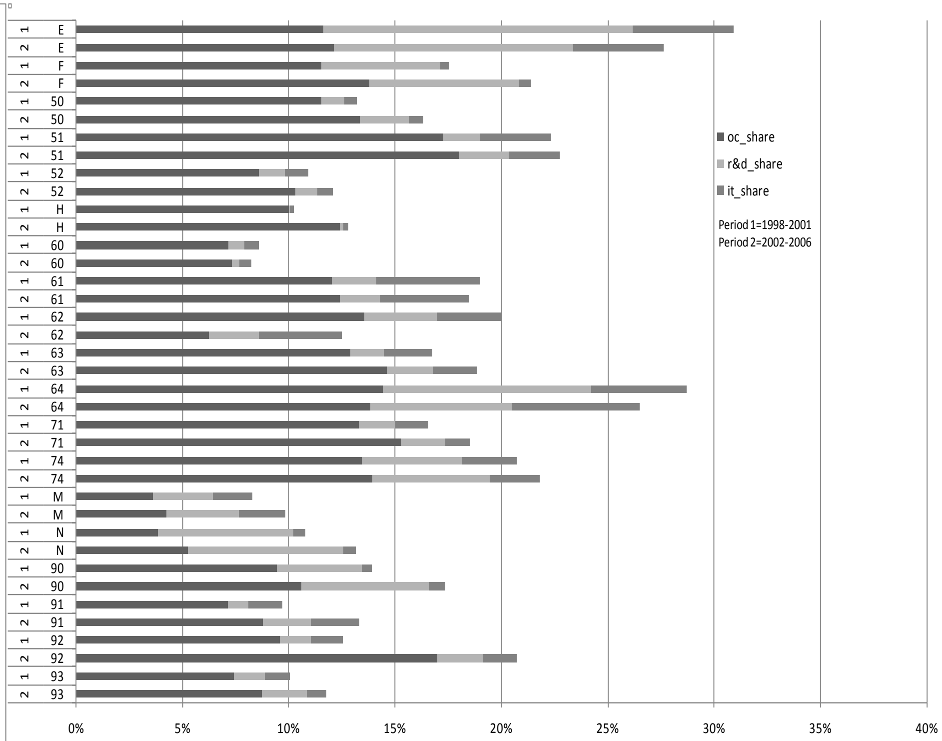
[7] Charts available on request

**Figure 3.4 a and b: Workers engaged in the production of intangibles 1998-2001 and 2002-2006 average**

(a) Production



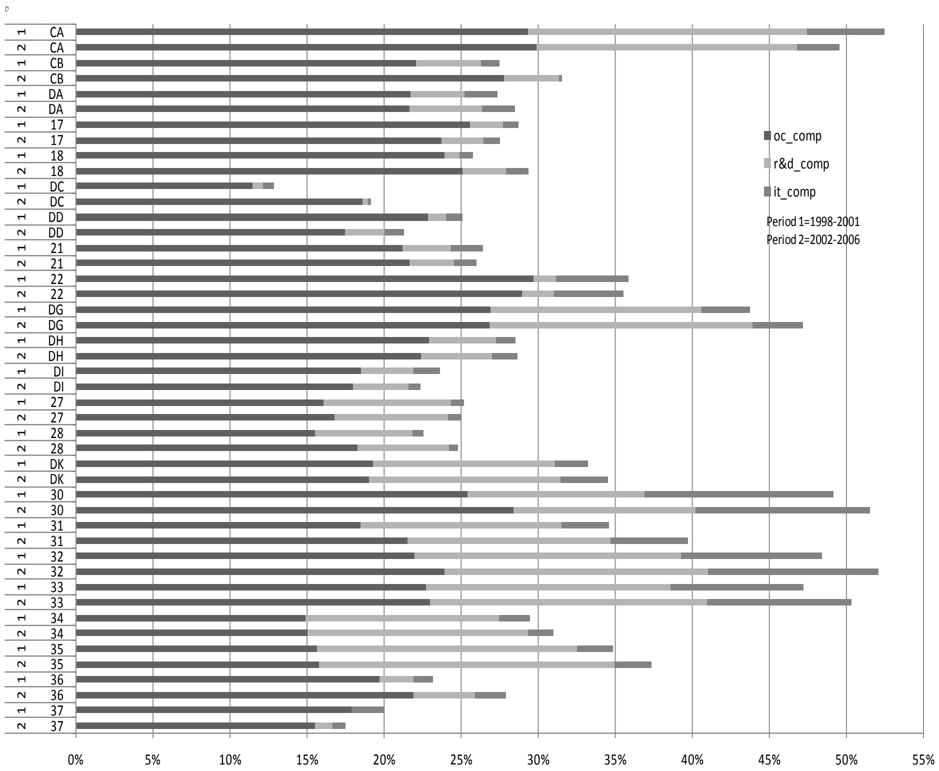
(b) Energy, Construction and Services



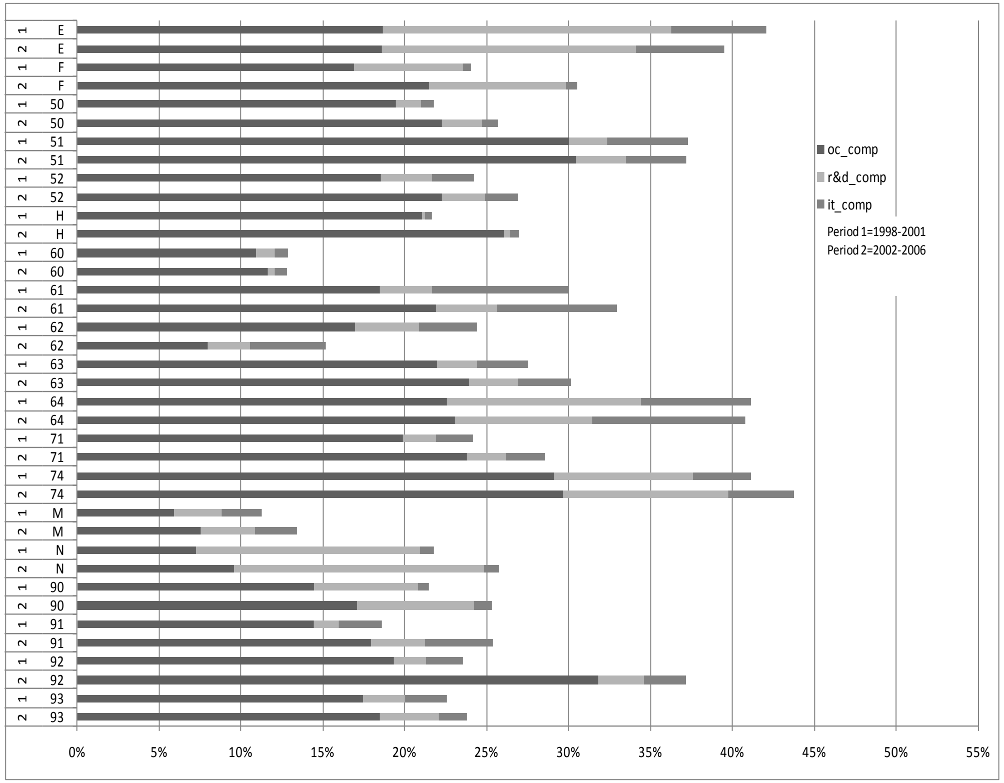
*Source: ABI; ASHE Various years, authors calculations.*

**Figure 3.5 a and b: Share of wages of workers engaged in the production of intangibles, 1998-2001 and 2002-2006 averages**

(a) Production



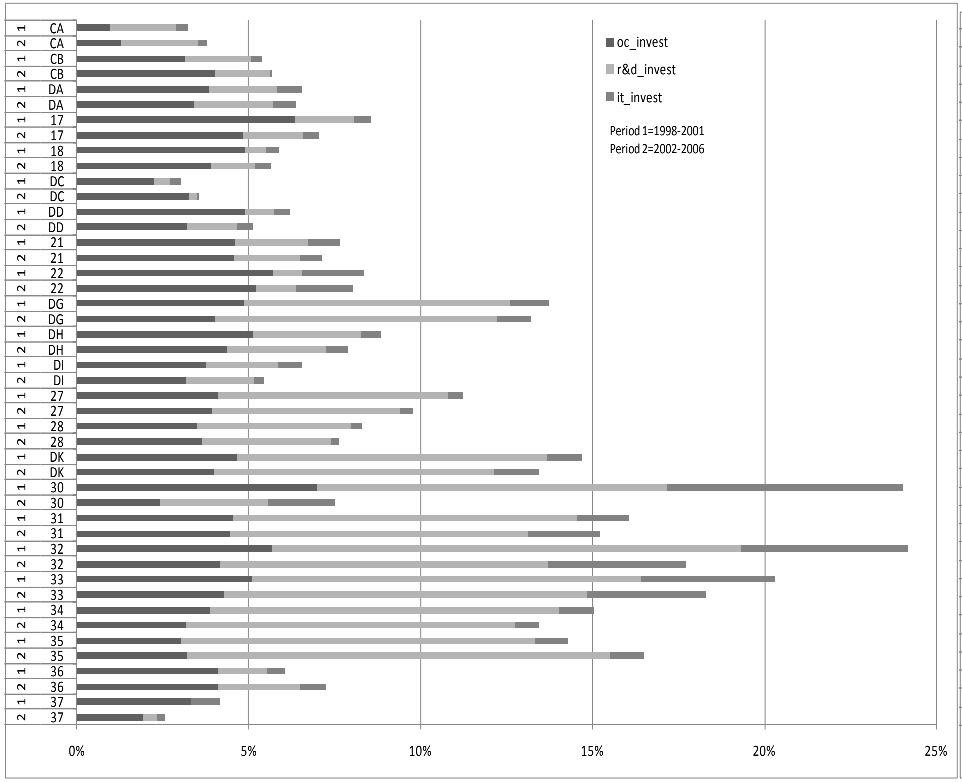

(b) Energy, Construction and Services



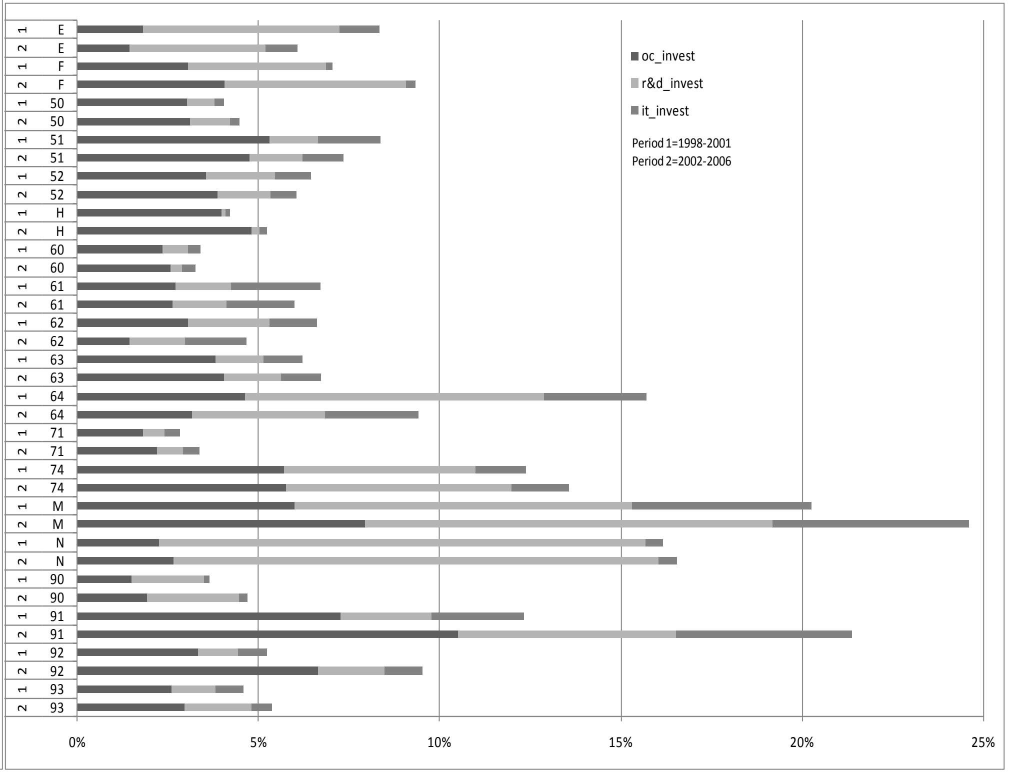

*Source: ABI, ASHE, various years, authors calculations*

**Figure 3.6 a and b: Intangible investment to GVA ratio 1998-2001 and 2002-2006 averages**

(a) Production




(b) Energy, Construction and Services




*Source: ABI; ASHE, various years, authors calculations.*

# 4. Intangible assets and performance

**Intangible assets are thought to have a positive impact on labour productivity. Here we test this, firstly across all firms and then specifically by sector. We use the A31 sectoral breakdown, subject to a number of exclusions because of data limitations.**

In this Chapter we use the firm level data constructed to analyse the individual effects of our intangible capital (disaggregated into IT, R&D and organisational workers as above) on productivity and productivity growth. In the first instance, we regress labour productivity on a number of inputs, incorporating intangibles as separate inputs. We begin by providing the basic methodology used before going on to present some descriptive statistics on our data. We then present our findings, firstly for the UK combined sample and secondly by sector.

## 4.1 Methodology

**We estimate labour productivity regressions using firm-level panel data. These are estimated for all sectors combined and secondly, by sector.**

In undertaking our econometric analysis we begin with a log linear specification of labour productivity:

$$\ln\left(GO/H_{it}\right) = \alpha_{it} + \beta_1 \ln Empsize2_{it} + \beta_2 \ln Empsize3_{it} + \beta_3 \ln TanK/H_{it} + \beta_4 \ln Mat/H_{it}$$
$$\beta_3 \ln ORG/H_{it} + \beta_4 \ln RD/H_{it} + \beta_5 \ln IT/H_{it} + \delta_i + T * I_{it} + \varepsilon_{it}$$

Where gross output per hour in firm *i* in period *t* is our dependent variable. We include two employment size bands to capture the effect of firm size; our estimate of capital stock intensity includes plant and equipment capital. Our measures of intangible capital intensity are separately constructed for three asset types (organisation workers, R&D workers and IT workers). We include industry and time fixed effects and their interactions.

We estimate simple Ordinary Least Squares (OLS) regressions for all sectors combined and separately. We include average wages to control for human capital. But, the effects of human and intangible capital are difficult to disentangle. We also estimate production functions excluding average wages. In addition to OLS estimates for individual sectors we report random and fixed effects estimates. It is important to emphasise, because of the potential for endogeneity, our firm level regressions can only provide associations between variables, not at this stage, establish causality. It is, for example, highly likely that high productivity firms are going to be better placed to invest in intangible assets. Disentangling these effects requires further work. The longitudinal element of the panel might be helpful in this regard.

## 4.2 Data description

**Capital stock data are not available for some sectors, however, a perusal of the full and restricted samples reveal that there are not substantial differences between these two datasets. Correlations reveal there to be a reasonable but not excessive degree of positive correlation between input and output variables to be analysed.**

Table 4.1 provides details of the sample used in the analysis. We present two samples since for around 17 per cent of the observations capital stock data are unavailable. Whilst this limits our sample in our full production function specifications, we are able to look at labour productivity for these firms. Table 4.1 confirms that for the full period, we have around 300,000 firm year observations but that neither the means nor the standard deviation of the variables look markedly different across the two samples.

Given the data limitations, we conduct our analysis at the NACE A31 level of aggregation which combines a number of two digit industries. For a full list of the NACE A31, see Appendix Table A.3. As discussed in Chapter 3, there are some notable sector exclusions, agriculture, financial intermediation and public sector dominated industries (Health and Education, Public administration) where outputs are difficult to measure.

**Table 4.1: Sample characteristics, 1998-2006**

| | Full Sample | | | Restricted Sample | | |
|---|---|---|---|---|---|---|
| | **Observations** | **mean** | **standard deviation** | **observations** | **mean** | **standard deviation** |
| log gva per hour | 337,247 | -4.27 | 0.90 | 278,576 | -4.27 | 0.91 |
| log gross output per hour | 346,576 | -3.34 | 1.04 | 285,687 | -3.28 | 1.01 |
| log firm employment | 346,667 | 3.14 | 1.88 | 285,769 | 3.06 | 1.84 |
| log intangible capital intensity (per hour) | 346,667 | -5.47 | 0.92 | 285,769 | -5.47 | 0.92 |
| log materials intensity (per hour) | 343,627 | -4.16 | 1.45 | 283,249 | -4.07 | 1.43 |
| log tangible capital intensity | 294,957 | -12.15 | 1.94 | 282,770 | -12.16 | 1.95 |
| log R&D capital intensity | 346,667 | -6.90 | 1.50 | 285,769 | -7.01 | 1.53 |
| log organisation capital intensity | 346,667 | -6.10 | 0.90 | 285,769 | -6.03 | 0.88 |
| log IT capital intensity | 346,667 | -8.18 | 1.38 | 285,769 | -8.12 | 1.40 |
| log labour quality index | 346,667 | 0.17 | 0.12 | 285,769 | 0.18 | 0.12 |

Table 4.2 contains the simple correlations between the variables in the analysis. In all cases, the correlations are statistically significant at the one per cent level, in part a feature

of a large dataset and to be expected given that all our variables are production variables. In all cases, the relationship is a positive one. Our dependent variable of choice, gross output per hour, is highly correlated with materials, as one would expect. It is also highly correlated with organisation capital (and hence also intangible capital), but to a lesser extent than value added per hour.

**Table 4.2: Variable correlations, 1998-2006**

| | log gva per hour | log gross output per hour | log firm employment | log intangible capital intensity | log materials intensity | log tangible capital intensity | log R&D capital intensity | log organisation capital intensity | log IT capital intensity |
|---|---|---|---|---|---|---|---|---|---|
| log gva per hour | 1 | | | | | | | | |
| log gross output per hour | 0.6883 | 1 | | | | | | | |
| log firm employment | 0.0676 | 0.0820 | 1 | | | | | | |
| log intangible capital intensity (per hour) | 0.6770 | 0.5723 | 0.1751 | 1 | | | | | |
| log materials intensity (per hour) | 0.3582 | 0.8351 | 0.0774 | 0.3961 | 1 | | | | |
| log tangible capital intensity | 0.1847 | 0.2065 | 0.0582 | 0.2053 | 0.1816 | 1 | | | |
| log R&D capital intensity | 0.4653 | 0.3371 | 0.0716 | 0.7673 | 0.2040 | 0.1492 | 1 | | |
| log organisation capital intensity | 0.6484 | 0.6145 | 0.1712 | 0.8990 | 0.4651 | 0.2027 | 0.5037 | 1 | |
| log IT capital intensity | 0.3950 | 0.2751 | -0.1197 | 0.5799 | 0.1381 | 0.1266 | 0.4292 | 0.4849 | 1 |
| log labour quality index | 0.2649 | 0.1440 | -0.0291 | 0.4861 | -0.0063 | 0.0818 | 0.3367 | 0.4278 | 0.4738 |

Note: Correlations presented for the full sample. The restricted sample correlations are similar. All correlations are significant at the 1% level.

### 4.3 Results

**Labour productivity, measured as gross output per hour, is regressed on a number of variables including firm size, materials, tangible capital (where available) average wages and our intangible capital stocks. Our results indicate that intangibles are significant and positively associated with labour productivity. Organisation capital has the largest coefficient in relation to labour productivity.**

Table 4.3 contains the results of our initial labour productivity regressions. These were estimated as pooled OLS regressions. In Model (1) we include employment size bands, split measures of intangible capital intensity and tangible capital. Because we are using a gross output specification, it is important to control for intermediate inputs (materials) also. The gross output specification is more general than a value added specification which nets out intermediates and therefore does not control for differences between input mixes. Beginning with Model (1) we see that with respect to the smallest employment size banding, the SME sector, size has a positive and significant association with labour productivity. In the case of our standard plant and machinery tangible capital measure, we see that this is also positive and significant (albeit with a relatively small coefficient). Our measure of tangible capital captures only plant and machinery, we therefore exclude property. This may partly explain why we find a relatively small coefficient on tangible capital. We note that the tangible capital coefficient becomes significantly larger when we estimate the model in dynamic form, although it is not clear to what extent this reflects the smaller sample available for estimating the dynamic model. Material input intensity is highly significant and has a large coefficient.[8]

Considering the variables of interest, the various intangible inputs, we see that all three are highly significant and positive, as we would expect. In terms of dominance, we see that the organisation capital term is the largest with R&D and IT of a similar order of magnitude to each other. Model (2) is applied to our full sample, but we are not able to include our tangible capital measure. This model is shown only to illustrate the sensitivity of the intangible capital coefficients to the sample. Our preferred model is Model (1). The sign and significance of our intangible capital intensity variables remain unaffected, however, we see that size in only a significantly meaningful characteristic for the very largest firms.

In Model (3) we include log hourly wage as an explanatory variable in order to take account of labour quality; the higher firm hourly wage, the more valuable the unit of labour input is. The coefficients attached to R&D and organisation intangible inputs become significantly

[8] The coefficient estimates here are in line with the material input share typically used in growth accounting calculations.

smaller but still very significant. Interestingly, we see that the coefficient associated with IT intangible capital intensity increases, as does tangible capital. Model (4) applies to the full sample (including those firms missing capital data) and therefore does not include capital intensity but does incorporate a control for labour quality (log hourly wage). Again, Model (3) is preferred to Model (4).

**Table 4.3: Labour productivity results, pooled OLS, 1998-2006**

| | **log gross output per hour** | | | | | |
|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
| | Baseline models | | Controlling for labour quality | | Restricted Sample | |
| Employment size band (250-2000) | 0.0119*** | -0.00295 | -0.0343*** | -0.0470*** | 0.0391*** | 0.00546 |
| | (0.0024) | (0.0024) | (0.0024) | (0.0023) | (0.00441) | (0.00423) |
| Employment size band (2000+) | 0.0829*** | 0.0924*** | 0.0175*** | 0.0212*** | 0.122*** | 0.103*** |
| | (0.0067) | (0.0054) | (0.0061) | (0.0050) | (0.00929) | (0.00769) |
| log hourly wage | | | 0.223*** | 0.249*** | | |
| | | | (0.0032) | (0.0031) | | |
| log R&D capital intensity (per hour) | 0.0322*** | 0.0475*** | 0.0187*** | 0.0270*** | 0.0214*** | 0.0264*** |
| | (0.0009) | (0.0009) | (0.0009) | (0.0009) | (0.00209) | (0.00202) |
| log organisation capital intensity (per hour) | 0.281*** | 0.262*** | 0.0888*** | 0.0566*** | 0.249*** | 0.243*** |
| | (0.0018) | (0.0018) | (0.0030) | (0.0030) | (0.00588) | (0.00557) |
| log IT capital intensity (per hour) | 0.0222*** | 0.0191*** | 0.0390*** | 0.0389*** | 0.00640*** | 0.00874*** |
| | (0.0009) | (0.0008) | (0.0009) | (0.0008) | (0.00164) | (0.00153) |
| log tangible capital | 0.0051*** | | 0.0064*** | | 0.0133*** | |
| | (0.0007) | | (0.0007) | | (0.00227) | |
| log materials intensity | 0.508*** | 0.504*** | 0.503*** | 0.496*** | 0.554*** | 0.553*** |
| | (0.0015) | (0.0014) | (0.0015) | (0.0014) | (0.00484) | (0.00435) |
| Constant | 0.787*** | 0.808*** | 0.771*** | 0.793*** | 0.551 | 0.600*** |
| | (0.0125) | (0.0419) | (0.0122) | (0.0445) | (679.7) | (0.0576) |
| | | | | | | |
| Observations | 280,634 | 343,539 | 280,634 | 343,539 | 41721 | 51545 |
| R-squared | 0.81 | 0.79 | 0.82 | 0.79 | 0.864 | 0.847 |

Note: Year *sector dummies included. Robust standard errors in parentheses; Asteriscs indicate statistical significance at the ***1%, **5%, *10% levels.

As well, we include Models (5) and (6). These are the same functions as Models (1) and (2) however, in order to test the sensitivity of our findings to the assumption underpinning the construction of our intangibles capital stock - the starting stock - we run the estimation removing the first four years of data for each firm in the sample. This means that by the time intangible capital stocks are in the estimated equation, a much smaller proportion of the stock is comprised of the starting value, they are composed mostly of the investment flows during the first four years. We note from Models (5) and (6) that the number of observations drops dramatically, from around 300,000 to around 45,000 as a result of all firms with less than five years of data being removed from the dataset. The significant change to the sample has an impact on the size of the coefficients; however it is clear that in terms of coefficient sign and significance, Models (5) and (6) are similar to Models (1) and (2). We also highlight the relative size of the coefficients on the intangible capital variables. For each of them, the sign and significance is consistent with the larger sample, and the relative ranking of the intangible capital types is also consistent across the two samples, with organisation capital clearly dominating. These results provide some indication that our key findings are robust to the assumptions made regarding the level of initial starting stocks.

### 4.4 Sector Results

**When estimated by sector, our results reveal some interesting findings. We note the importance of including log hourly wage to net out some of the human capital effects. Without this, intangible measures are substantially higher. Also, we find R&D to be particularly sector specific. IT and to a lesser extent, organisation capital appear to be more generic in their association. Sectors for which organisation capital have a relatively large coefficient include the more traditional sectors of wood and cork production and textiles. In services, we note other community and social work as well as hotels and restaurants reveal the highest coefficients on organisation capital.**

The findings above apply to our subsample of firms in the UK which cover a broad range of market sectors. In general therefore we can see that intangible capital intensity has a strongly positive and significant association with labour productivity and that overall, organisation capital intensity has the largest effect, even when labour quality is controlled for with the inclusion of hourly wages. Although sector controls have been included in the above estimates, in order to understand how the impact of intangible capital intensity may vary across sectors, it is useful perhaps to consider findings by estimating the production equation by sector. In Table 4.4a and 4.4b we present estimates of Model (3) above for a number of UK sectors. We are constrained by our sample to analyse 20 sectors, given that our coverage of agriculture is partial, we have no data for financial intermediation, capital stocks data were not available for a number of other sectors also, including construction and electricity gas and water supply, public administration, and health and education. Thus our list of the A31 industries is truncated somewhat.

Table 4.4a contains the results for the majority of manufacturing industries, covering sectors CA (mining) to 30-33 (electrical and optical equipment). Reporting on the overall specification we see that the employment size bands have mixed effects over the various sectors. Our measure of labour quality – log hourly wage – is always positive and significant, but is highest in mining and quarrying and electrical and optical equipment. Materials maintain a fairly stable coefficient across sectors but are always positive and significant and tangible capital, whilst small, is generally positive and significant in all but textiles.

Our three measures of intangible capital intensity within the sectors are also presented in Table 4.4a. The coefficient on R&D intangible capital intensity is largest in mining and quarrying and insignificant in a number of the more mature, low technology sectors such as food, drink and tobacco, textiles, machinery not elsewhere included and interestingly, electrical and optical equipment. Indeed, whilst the coefficient is not significantly different from zero, it has a negative sign in some cases. Thus, the association between R&D intangible capital and labour productivity shows signs of being concentrated in certain industries.

Organisation capital intensity, with the exception of mining and quarrying, is always positive and significant. The coefficient is particularly large in the more traditional manufacturing sectors such as wood products, textiles and machinery not elsewhere specified. Finally, if we look at the role IT capital intensity plays in labour productivity by sector, we note that this seems particularly generic in its positive association (arguably because of it being a general purpose technology). The variation in the magnitude of the coefficients across sectors is relatively small, although it is at its smallest in relation to other non-metallic mineral products and largest with respect to printing and publishing.

Table 4.4b contains transport equipment and manufacturing not elsewhere included, as well as service sectors. Transport equipment is the only manufacturing sector for which R&D and organisation capital intensity are not significant. Other sectors included in Table 4.4b are services. Here we see the log hourly wage has a smaller association with labour productivity compared with manufacturing. R&D capital intensity is not significant in the wholesale sectors, but is significant in retail. Nor is it significant in transport, storage or telecommunications. Organisation capital intensity is significant and positive in all service sectors included, although it makes a large contribution to labour productivity in hotels and restaurants and in other community, social and personal services. IT capital intensity is positive and significant, the coefficients, by and large, are larger in the case of services (consistent with van Ark's work on IT using sectors benefitting from IT growth). Other business activities and transport and storage (logistics) are sectors that experience the highest contribution from IT capital intensity to labour productivity.

It is worth pointing out that the association of the sum of the intangible capital intensities with labour productivity is significantly larger than the tangible capital and the coefficients on tangible capital are perhaps lower than one would expect.  This may be for number of reasons, as discussed above.

Overall there appears to be no recognisable pattern or sectoral groupings consistent with other studies of knowledge based indicators, such as high skills, IT or technology (like those identified in the earlier work of O'Mahony and van Ark, 2003).  Our findings are more in line with the general findings in relation to management practices (Bloom et al, 2010): an across the board significance.  It seems to be the case that whilst there are differences in the relative importance of the components of intangible capital, overall they have a positive and significant association with labour productivity.

**Table 4.4a: sector results, dependent variable log gross output per hour (pooled OLS)**

| | Mining and quarrying | Food, beverages and tobacco | Textiles, leather and footwear | Wood and cork | Pulp, paper, printing and publishing | Chemicals, rubber plastics and fuel | Other non-metallic mineral products | Basic and fabricated metals | Machinery NEC | Electrical and optical equipment |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment size band (250-2000) | -0.345*** | -0.111*** | -0.053*** | -0.015 | 0.002 | -0.058*** | -0.026* | -0.038*** | 0.008 | 0.050*** |
| | (0.109) | (0.010) | (0.009) | (0.037) | (0.013) | (0.008) | (0.014) | (0.010) | (0.010) | (0.010) |
| Employment size band (2000+) | -0.339*** | 0.014 | -0.055 | -0.201*** | 0.105*** | 0.020 | 0.024 | 0.047 | 0.046 | 0.087 |
| | (0.109) | (0.033) | (0.044) | (0.033) | (0.033) | (0.038) | (0.022) | (0.066) | (0.037) | (0.054) |
| log hourly wage | 0.361*** | 0.308*** | 0.257*** | 0.130*** | 0.308*** | 0.319*** | 0.298*** | 0.225*** | 0.340*** | 0.393*** |
| | (0.075) | (0.020) | (0.026) | (0.049) | (0.028) | (0.022) | (0.030) | (0.014) | (0.020) | (0.023) |
| log R&D capital intensity (per hour) | 0.208** | -0.009** | -0.002 | 0.086*** | 0.035*** | 0.039*** | 0.021*** | 0.076*** | -0.041*** | -0.058*** |
| | (0.083) | (0.005) | (0.005) | (0.016) | (0.008) | (0.010) | (0.005) | (0.007) | (0.013) | (0.013) |
| log organisation capital intensity (per hour) | -0.164* | 0.092*** | 0.156*** | 0.158*** | 0.071*** | 0.015 | 0.072*** | 0.110*** | 0.086*** | 0.074*** |
| | (0.093) | (0.016) | (0.020) | (0.053) | (0.025) | (0.014) | (0.021) | (0.012) | (0.015) | (0.015) |
| log IT capital intensity (per hour) | 0.031 | 0.033*** | 0.024*** | 0.050*** | 0.070*** | 0.026*** | 0.009** | 0.048*** | 0.021*** | 0.016*** |
| | (0.020) | (0.003) | (0.003) | (0.008) | (0.009) | (0.003) | (0.004) | (0.002) | (0.003) | (0.005) |
| log tangible capital intensity (per hour) | 0.016 | 0.018*** | -0.004* | 0.014** | 0.005** | 0.008*** | 0.015*** | 0.005*** | 0.001 | 0.006* |
| | (0.013) | (0.004) | (0.002) | (0.007) | (0.002) | (0.003) | (0.005) | (0.002) | (0.002) | (0.003) |
| log materials intensity (per hour) | 0.472*** | 0.555*** | 0.520*** | 0.479*** | 0.413*** | 0.531*** | 0.517*** | 0.446*** | 0.469*** | 0.481*** |
| | (0.037) | (0.010) | (0.010) | (0.019) | (0.011) | (0.010) | (0.018) | (0.008) | (0.011) | (0.009) |
| Constant | 0.960** | 2.260*** | 1.108*** | 1.379*** | 1.128*** | 0.961*** | 0.954*** | 1.158*** | 0.637*** | 0.707*** |
| | (0.427) | (0.297) | (0.082) | (0.149) | (0.073) | (0.061) | (0.104) | (0.049) | (0.059) | (0.059) |
| | | | | | | | | | | |
| Observations | 719 | 7084 | 5939 | 2287 | 9370 | 9198 | 3063 | 12862 | 7959 | 8640 |
| Number of firms | 0.781 | 0.867 | 0.861 | 0.799 | 0.789 | 0.868 | 0.836 | 0.807 | 0.787 | 0.827 |

Note: Year dummies included. Robust standard errors in parentheses; Asteriscs indicate statistical significance at the ***1%, **5%, *10% levels.

**Table 4.4b: Sector results, continued**

| | Transport equipment | Manufact-uring NEC | Sale & repair of motor vehicles ; retail of fuel | Wholesale, except of motor vehicles and motorcycles | Retail trade; repair of household goods | Hotels and Restaurants | Transport and Storage | Post and Telecoms | Renting and other business activities | Other Community social services |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment size band (250-2000) | -0.040*** | -0.102*** | -0.053*** | -0.011 | -0.040*** | -0.102*** | -0.160*** | -0.039 | -0.096*** | 0.134*** |
| | (0.013) | (0.010) | (0.008) | (0.009) | (0.005) | (0.009) | (0.011) | (0.028) | (0.006) | (0.016) |
| Employment size band (2000+) | 0.111*** | -0.164* | -0.033** | 0.023 | -0.032*** | -0.021 | -0.104*** | 0.018 | 0.003 | 0.226*** |
| | (0.035) | (0.089) | (0.017) | (0.019) | (0.005) | (0.015) | (0.020) | (0.039) | (0.016) | (0.034) |
| log hourly wage | 0.325*** | 0.229*** | 0.176*** | 0.156*** | 0.172*** | 0.148*** | 0.239*** | 0.215*** | 0.224*** | 0.073*** |
| | (0.028) | (0.025) | (0.008) | (0.013) | (0.005) | (0.011) | (0.014) | (0.039) | (0.007) | (0.017) |
| log R&D capital intensity (per hour) | -0.006 | 0.019*** | 0.003 | -0.002 | 0.029*** | 0.009*** | 0.009*** | 0.017*** | 0.041*** | -0.027*** |
| | (0.008) | (0.005) | (0.004) | (0.003) | (0.002) | (0.002) | (0.003) | (0.006) | (0.003) | (0.005) |
| log organisation capital intensity (per hour) | 0.030 | 0.072*** | 0.000 | 0.051*** | 0.008 | 0.230*** | 0.065*** | 0.072 | 0.122*** | 0.328*** |
| | (0.020) | (0.023) | (0.009) | (0.014) | (0.006) | (0.011) | (0.016) | (0.049) | (0.007) | (0.018) |
| log IT capital intensity (per hour) | 0.029*** | 0.049*** | 0.027*** | 0.027*** | 0.055*** | 0.079*** | 0.097*** | 0.057** | 0.122*** | 0.054*** |
| | (0.004) | (0.006) | (0.003) | (0.002) | (0.003) | (0.003) | (0.006) | (0.027) | (0.005) | (0.008) |
| log tangible capital intensity (per hour) | 0.018*** | 0.012*** | 0.001 | 0.003* | -0.000 | 0.009*** | 0.036*** | 0.027*** | 0.015*** | 0.019*** |
| | (0.005) | (0.004) | (0.002) | (0.002) | (0.001) | (0.001) | (0.006) | (0.009) | (0.002) | (0.004) |
| log materials intensity (per hour) | 0.491*** | 0.509*** | 0.707*** | 0.702*** | 0.625*** | 0.444*** | 0.512*** | 0.472*** | 0.321*** | 0.455*** |
| | (0.013) | (0.012) | (0.006) | (0.004) | (0.005) | (0.006) | (0.006) | (0.015) | (0.003) | (0.006) |
| Constant | 0.823*** | 1.046*** | 0.624*** | 0.755*** | 0.635*** | 1.446*** | 1.939*** | 1.098*** | 0.975*** | 1.518*** |
| | (0.102) | (0.098) | (0.041) | (0.027) | (0.020) | (0.036) | (0.106) | (0.101) | (0.045) | (0.082) |
| | | | | | | | | | | |
| Observations | 4314 | 5439 | 16549 | 37177 | 40886 | 21095 | 15219 | 1803 | 50003 | 20460 |
| Number of firms | 0.807 | 0.805 | 0.915 | 0.891 | 0.830 | 0.765 | 0.837 | 0.819 | 0.757 | 0.598 |

Note: Year dummies included. Robust standard errors in parentheses; Asteriscs indicate statistical significance at the ***1%, **5%, *10% levels.

### ***Robustness checks***

The findings presented in Tables 4.4a and 4.4b are our preferred estimates. As previously argued, we include log hourly wage to separate human capital or labour quality effects from the intangible capital associations with productivity. However, it could be argued that by including the measure of hourly wage we are overcompensating for the labour quality effect[9]. As the reality probably lies somewhere in the middle, we present in Tables A4a and A4b (see Appendix) findings without the inclusion of log hourly wage, thus, these findings are more directly comparable to our Model (1) in Table 4.3. Here again, we use a standard, pooled OLS. The results in Tables A4a and A4b compared to Tables 4.4a and b show the coefficient associated with organisation capital intensity increases in magnitude when hourly wage is omitted. Only in mining and quarrying and electrical and optical equipment does IT intensity become insignificant compared with the estimates in Table 4.4a.

The differences between our findings with and without our labour quality control may be summarised thus: without the hourly wage, R&D becomes significant in all except wholesale and transport and storage. This contrasts with the initial findings, where R&D appeared more sector specific. The coefficients on organisational capital are much larger and always positive and significant. We observe little change in the IT capital term. In summary therefore, it appears as though our labour quality control, when omitted, falls mainly into the organisation capital intensity term, rather than R&D or IT.

The results contained in Tables 4.4 and A4 are estimated using OLS, that is, each firm and year observation is treated independently as an observation. A criticism of any regression approach is that we are not able to control for a great deal of omitted variables. In the case of panel data, it is possible to apply more sophisticated techniques that allow us to control for unobserved differences by looking at firms over time. This approach enables us to control for unobserved 'fixed' effects that exist within firms, without knowing what they are. Therefore, we estimate our labour productivity equation using fixed and random effects estimators, suited to panel data. By providing these estimates we are able to test the robustness and consistency of our findings using the OLS approach. If our findings are similar across all methods, we could say with more confidence that the association we are finding is a stable one.

In Tables A5a and A5b and Tables A6a and A6b, we present random and fixed effect estimates for all industries. Whilst the size of the coefficients varies, we note that

[9] We thank Andy Dickerson for this point.

organisation capital is (as above) significant and positive in all cases. R&D appears to be more consistent with our findings in Tables 4.4 in that it is not significant in a number of lower technology manufacturing sectors for the fixed effects estimator, however it is more positive and significant across the array of industries in the random effects models (Tables A5a and A5b). Note the negative impact of R&D intensity in food and beverages using the OLS and random effects estimators (insignificant using the fixed effects estimator).

# 5. Spatial and Industrial Heterogeneity

**Intangibles affect industries and regions differently. In this Chapter we use the growth accounting methodology to look at the relative contributions to growth made by intangible assets.**

As well as individual firm level effects on productivity levels, we explore differences in intangible capital across industries and regions and the effect they have on productivity growth[10]. Traditional regional analysis has used administratively defined areas, such as government office regions or local authorities or detailed data on travelling distances. Regardless of the level of detail, all administrative regions have little to do with the way in which economies behave. We therefore adopt a more meaningful structure by using city regions in Great Britain[11], constructed on the basis of the commuting patterns of the highly skilled (Robson et al, 2006). A full list of these city regions is provided in Table 5.1; however, given that these do not follow standard, administrative boundary definitions, Figure 5.1 provides a summary of employment intensity (number of jobs) across the UK in 2004 using the city-region boundaries[12].

The city regions used in this project do not directly correspond to existing local enterprise partnerships (LEPs) recently formed as a consequence of the Government White Paper, BIS (2010). It is however very much in the spirit of current thinking with respect to economic geography.

The overlap between our city-regions and LEPs is quite considerable in some areas, although for example, Greater London city region is larger than the London LEP. This is likely to be a consequence of there being a high concentration of economic activity in the South East. The city regions used here have been constructed on the basis of high skilled commuting patterns and this is likely to result in larger conurbations than the LEP boundaries.

In Table 5.1 we list the city regions in full, shading out those that are excluded from the analyses. The areas not covered by the analysis account for less than 20 per cent of employment and GVA for the whole of the UK. Average employment shares over the period give some indication of the relative size of each of the city region and the labour productivity

[10] Productivity growth is more about the trajectory an industry or region is following rather than the level of productivity in an industry or region.
[11] The dataset used contained no observations for Northern Ireland and therefore only covers Great Britain.
[12] Note that we focus on Great Britain and also exclude residual categories from our analysis. These are parts of regions not elsewhere included and have little meaning - other Wales, for example.

level is provided in the final column. As we would expect, Greater London accounts for a substantial share of employment and GVA and has an above average level of labour productivity. Aberdeen has an exceptionally high level of GVA per hour (employment is concentrated in high capital intensive mining), but accounts for less than one per cent of employment. Dundee, Swansea and Exeter have comparatively low levels of labour productivity over the period, whilst Reading, Luton, Swindon and Milton Keynes seem to be relatively productive city-regions.

**Table 5.1: Summary variables of city regions of the UK included, 1998-2006 average**

| City Region | Firm count (sample) | % employment (average 1998-2006) | % GVA (average 1998-2006) | GVA per hour (average (1998-2006) |
|---|---|---|---|---|
| Birm/Sand/Wolver | 1,803 | 4.66 | 3.87 | 14.81 |
| Bournemouth/Poole | 323 | 0.60 | 0.45 | 13.50 |
| Brighton/Hove | 235 | 0.48 | 0.36 | 13.63 |
| Bristol/S. Glouc | 628 | 1.41 | 1.16 | 14.66 |
| Cambridge | 241 | 0.56 | 0.47 | 15.46 |
| Carlisle | 178 | 0.34 | 0.25 | 12.38 |
| Chester | 280 | 0.45 | 0.59 | 21.79 |
| Colchester | 164 | 0.28 | 0.21 | 13.60 |
| Coventry | 380 | 1.04 | 1.06 | 17.72 |
| Exeter | 291 | 0.61 | 0.34 | 10.34 |
| Greater London | 8,119 | 35.33 | 42.10 | 21.91 |
| Glouc/Chelt | 334 | 0.69 | 0.63 | 16.04 |
| Ipswich | 287 | 0.56 | 0.58 | 17.91 |
| Kingston upon Hull | 359 | 0.70 | 0.62 | 15.45 |
| Leeds/Bradford | 1,646 | 3.98 | 3.20 | 14.44 |
| Leicester | 562 | 1.16 | 0.91 | 13.81 |
| Lincoln | 153 | 0.39 | 0.26 | 11.95 |
| Liverpool | 502 | 1.38 | 0.95 | 12.82 |
| Luton | 157 | 0.39 | 0.48 | 20.98 |
| Manchester/Salford/Trafford | 1,861 | 4.87 | 4.43 | 16.05 |
| Middlesborough/Stockton | 366 | 0.95 | 0.95 | 17.42 |
| Milton Keynes | 163 | 0.37 | 0.50 | 21.76 |
| Newcastle/Gates/Sund | 813 | 2.22 | 1.98 | 15.80 |
| Northampton | 319 | 0.67 | 0.61 | 15.49 |
| Norwich | 373 | 0.74 | 0.49 | 11.91 |
| Notts/Derby | 787 | 1.98 | 2.18 | 19.21 |
| Oxford | 358 | 0.92 | 0.80 | 16.41 |
| Peterborough | 300 | 0.63 | 0.56 | 15.30 |
| Plymouth | 240 | 0.48 | 0.32 | 11.69 |
| Portsmouth/Southampton | 735 | 1.53 | 1.36 | 15.97 |
| Preston | 167 | 0.33 | 0.27 | 14.80 |
| Reading | 331 | 0.77 | 1.50 | 33.31 |

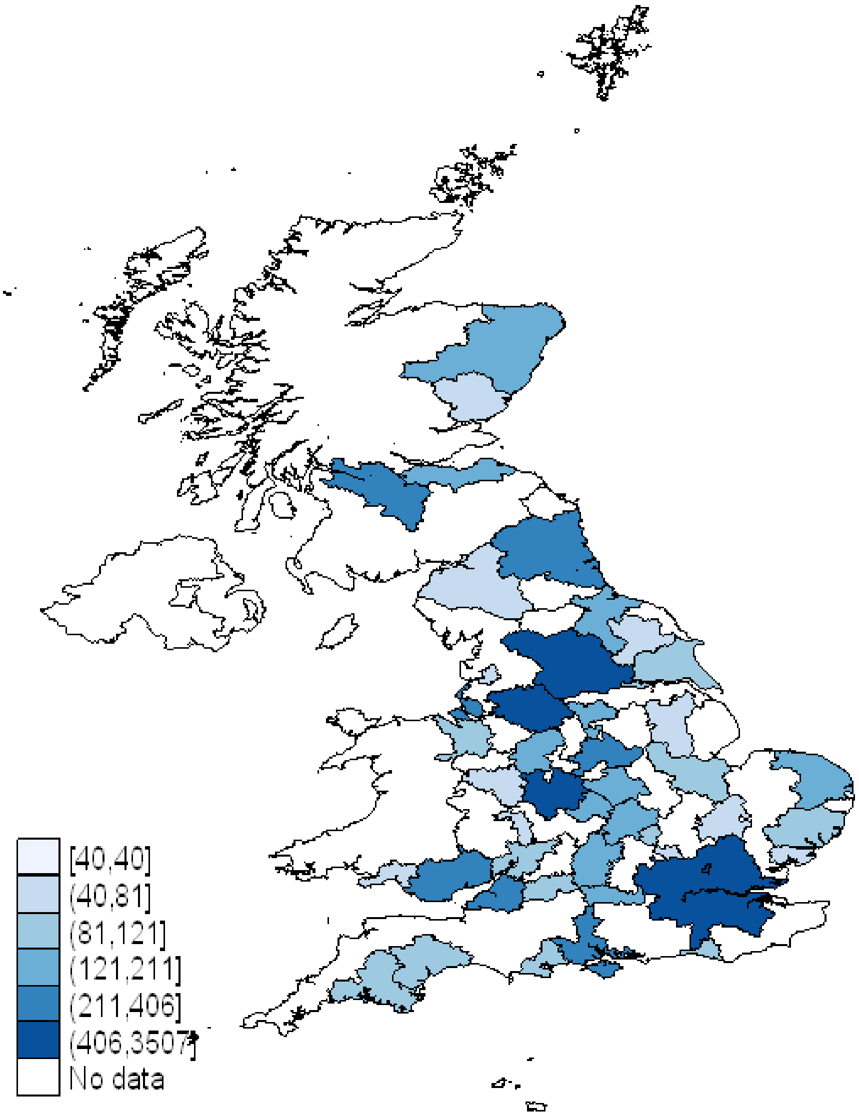
| | | | | |
|---|---|---|---|---|
| Sheffield | 509 | 1.12 | 0.78 | 12.12 |
| Stoke on Trent | 349 | 0.91 | 0.63 | 12.27 |
| Swindon | 196 | 0.48 | 0.81 | 27.00 |
| Telford and Wrekin | 205 | 0.43 | 0.35 | 14.04 |
| Worcester | 117 | 0.26 | 0.18 | 12.25 |
| York | 156 | 0.41 | 0.42 | 17.09 |
| Cardiff | 1,147 | 1.73 | 1.41 | 14.51 |
| Swansea | 172 | 0.24 | 0.14 | 10.27 |
| Aberdeen | 616 | 0.84 | 2.46 | 47.74 |
| Dundee | 210 | 0.28 | 0.16 | 10.48 |
| Edinburgh | 663 | 1.04 | 0.81 | 14.03 |
| Glasgow | 1,279 | 2.22 | 1.84 | 14.61 |
| *Other NE* | 118 | *0.19* | *0.19* | *16.98* |
| *Other NW* | 1,302 | *2.82* | *2.41* | *15.20* |
| *Other Y&H* | 582 | *1.26* | *0.97* | *13.16* |
| *Other WM* | 805 | *1.50* | *1.20* | *13.84* |
| *Other EM* | 588 | *1.06* | *1.00* | *15.89* |
| *Other Eastern* | 977 | *1.85* | *1.88* | *17.35* |
| *Other SE* | 1,686 | *3.77* | *3.66* | *17.68* |
| *Other SW* | 1,240 | *2.50* | *1.66* | *12.03* |
| *Other Wales* | 1,057 | *1.26* | *0.85* | *12.21* |
| *Other Scotland* | 1,803 | *2.33* | *1.77* | *13.43* |

Note: Shaded City Regions are excluded from analysis.  Source: BSD, ARD, ASHE, various years.

Figure 5.1 shows the various boundaries of the city regions by providing employment concentration in 2004.  It is apparent that Greater London, for example, is considerably larger than its standard definition, incorporating parts of the Home Counties that are within a reasonable commute of London.  Here we see the largest concentration of employment, along with areas such as Birmingham, and Liverpool. In contrast, job intensity is less strong in the more remote regions, such as the South West and also parts of Eastern England.

We provide growth accounting estimates, by industry and also by city region.  These are firm level data that have been aggregated but are weighted to be representative of the population.

**Figure 5.1: Jobs in UK City Regions, 2004 (Non-farm business sector; thousands)**




*Source: BSD, ONS*

## 5.1 Growth accounting methodology

**As an alternative to econometric estimation of associations, the growth accounting methodology can be applied to decompose productivity growth into its component parts, including intangible capital.**

The growth accounting approach to total factor productivity growth estimation has been used to estimate the impact of IT on productivity by Jorgenson and Stiroh (2000) and Oliner and Sichel (2000). It is useful in that it allows for the decomposition of output growth into contributions from factor inputs and underlying productivity growth or TFP. Assume the production function of a firm in industry (j) may be written:

$$Q_{jt} = A_{jt} f(L_{jt}, K_{jt}) \tag{4}$$

Where Q is real output (here measured as real value added), K and L are the capital and labour inputs, respectively, and A is technical progress or total-factor productivity (hereafter, TFP). Assuming perfectly functioning markets and constant returns to scale, TFP can be calculated as an index. Assuming a translog production function, output growth can be decomposed into its various components in the following way (Jorgensen, 1987):

$$\Delta \ln Q_{jt} = \Delta \ln A_{jt} + \alpha_{jt} \Delta \ln L_{jt} + (1 - \alpha_{jt}) \Delta \ln K_{jt} \tag{5}$$

Where $\alpha_{jt}$ is the share of labour in value added (labour costs divided by value added) averaged over period *t* and *t-1*. In studies relating to the impact of IT on productivity, this has involved quality adjustment of capital, accounting for substitution between new technology and traditional capital. Other studies have adjusted for labour quality (c.f. O'Mahony and Van Ark, 2003; O'Mahony and Robinson, 2007), and we discussed in Chapter 4 why this might be relevant with regards to intangible investment.

In order to incorporate intangibles we need to adjust both the input and output sides of equations (4) and (5); see Corrado et al. (2006). Output needs to be adjusted to include intangible investment output and the production function needs to take into account services from the intangible capital stock. The production function becomes:

$$Q^*_{jt} = A^*_{jt} f^*(L_{jt}, K_{jt}, K_{OCjt}, K_{R\&Djt}, K_{ITjt}) \tag{6}$$

where, $Q^*_{jt} \equiv Q_{jt} + I_{OCjt} + I_{R\&Djt} + I_{ITjt}$, and where $I_{IC}$ and $K_{IC}$, for $IC = OC, R\&D, IT$, are as defined previously. Output growth (adjusted for intangibles) can then be decomposed into the contributions from labour, tangible and intangible capital as:

$$\Delta \ln Q^*_{jt} = \Delta \ln A^*_{jt} + \alpha^*_{jt} \Delta \ln L_{jt} + (1 - \alpha^*_{jt} - \sum_{IC} \alpha_{ICjt}) \Delta \ln K_{jt} + \sum_{IC} \alpha_{ICjt} \Delta \ln K_{ICjt} \tag{7}$$

where $\alpha^*_{jt}$ is the share of labour in value added adjusted for intangibles, and $\alpha_{ICjt}$ is the share of intangible capital costs in valued added adjusted for intangibles for $IC = OC, R\&D, IT$. In calculating intangible capital cost shares we follow Görzig et al.

(2011), setting the user cost of intangible capital to the sum of the depreciation rate (in Table 3.4 above) and an external rate of return of four per cent per annum. The return to tangible capital is then derived by residual using the constant returns to scale assumptions.

Rearranging equation (7) we can decompose labour productivity growth (adjusted for intangibles) into the contributions from tangible and intangible capital, and from the unexplained technology component, $A^{*}_{jt}$, as:

$$\Delta \ln(Q^{*}_{jt} / L_{jt}) = \Delta \ln A^{*}_{jt} + (1-\alpha^{*}_{jt} - \sum_{IC} \alpha_{ICjt}) \Delta \ln(K_{jt} / L_{jt}) + \sum_{IC} \alpha_{ICjt} \Delta \ln(K_{ICjt} / L_{jt}) \qquad (8)$$

In Tables 5.2 to 5.4 we show growth in adjusted (for intangibles) productivity by sector, $\Delta \ln(Q^{*}_{jt} / L_{jt})$, and the contributions from intangible capital deepening, $\alpha_{ICjt} \Delta \ln(K_{ICjt} / L_{jt})$, for each of the three types of intangible capital considered in this report. We also show the difference between growth in adjusted and unadjusted productivity, $\Delta \ln(Q^{*}_{jt} / L_{jt}) - \Delta \ln(Q_{jt} / L_{jt})$. The results by sector (split into production sectors and construction and services sectors) are shown for the periods 1999-2001 and 2003 to 2006 (we do not assess growth between 2001 and 2002 because of the change in SOC codes).

Table 5.2 gives an overview of the contributions intangible capital has made to labour productivity growth to aggregate market sectors and the total market economy, with a number of exclusions discussed earlier. Note that the total market economy category includes mining, construction and utilities as well as manufacturing and market services. Labour productivity growth is defined as Gross Value Added per hour worked and is adjusted to take account of the addition of intangible capital. We compare the periods 1998-2001 and 2003-2006. Overall we see that labour productivity growth is higher in the second period compared with the earlier period, increasing from around 2.7 per cent per annum to 4.1 per cent by 2003-2006. The inclusion of intangibles in the early period raises labour productivity growth in manufacturing (0.10%, per year), whilst there is a slight decline in the market service industries (-0.01%, per year). In the latter half of the period, we note that the adjustment is negative in both manufacturing and services. This means that during 2003-2006 intangible investment rose less quickly than GVA (the ratio of intangible investment to GVA was falling).

Turning to the contributions from the intangible inputs, we see that in both periods, for all components of intangible capital, the contributions are positive. In the case of manufacturing, R&D is the more dominant form of intangible capital. Labour productivity growth in market services is more evenly affected although organisation capital is slightly stronger than the others. In the later period, we note that the contributions from all forms of intangibles declines, however the patterns between the various components remain; R&D is still dominant in manufacturing while organisation capital makes a larger contribution to labour productivity growth in market services. Throughout, the contribution of IT capital has been relatively steady, with the exception of manufacturing in the later period. The total market economy figures reflect the relative importance of services, compared with manufacturing.

**Table 5.2: Contributions of intangible capital to Labour productivity growth (LPG), 1998-2006**

| | | | | Contribution of intangible capital to LPG | | | |
|---|---|---|---|---|---|---|---|
| | Firm count | adjusted-unadjusted LPG | Adjusted LPG | OC | R&D | IT | Total |
| **1998-2001** | | | | | | | |
| Manufacturing (sectors 15-37) | 10,455 | 0.10% | 3.07% | 0.17% | 0.38% | 0.10% | 0.65% |
| Market Services (sectors 50 to 93, excluding financial services, L, M and N) | 25,353 | -0.01% | 2.84% | 0.18% | 0.12% | 0.16% | 0.45% |
| Total Market Economy (excluding agriculture, financial services, education and health) | 39,114 | 0.02% | 2.63% | 0.17% | 0.17% | 0.13% | 0.46% |
| | | | | | | | |
| **2003-2006** | | | | | | | |
| Manufacturing (sectors 15-37) | 9,089 | -0.18% | 4.33% | 0.09% | 0.25% | 0.03% | 0.37% |
| Market Services (sectors 50 to 93, excluding financial services, L, M and N) | 23,858 | -0.19% | 4.20% | 0.14% | 0.11% | 0.11% | 0.36% |
| Total Market Economy (excluding agriculture, financial services, education and health) | 36,253 | -0.11% | 3.49% | 0.12% | 0.13% | 0.08% | 0.33% |

*Source: ABI; ASHE Various years, authors calculations.*

## 5.2 Industry differences in intangible contributions to labour productivity growth

**The growth accounting methodology is applied to an industry database including intangible capital, enabling us to explore the sector contributions of intangible capital, by asset type, to labour productivity growth. We find that the contribution to productivity growth of R&D intangible capital is sector specific. The role of organisational capital is substantial across many industries. Sectors with particularly high contributions from intangible capital include Research and development, Computer and related activities and the Manufacture of motor vehicles.**

As we saw in Chapter 3, industries differ in their composition and use of intangible capital in much the same way as with any input. Given this, we explore the contributions these inputs make to labour productivity growth using the growth accounting method outlined above. In some ways, growth accounting is an alternative to econometric estimation and in this case, we use industry and not the firm level data analysed in Chapter 4. Thus, this provides the aggregate sector picture of the relationship between intangibles and labour productivity growth. Table 5.3a and b provide growth accounting results for production sectors over the two periods of analysis (1998-2001 and 2003-2006). As well as providing the sample sizes on which the sector results are based (the average number of firms each year) we also provide an indication of the impact that intangibles have on growth in value added per hour (growth in labour productivity). The columns of interest within the tables have been shaded on the basis of largest (dark grey) to smallest (white) to explore whether within the whole range of contributions to labour productivity growth, there are patterns across intangible asset types (IT, R&D or OC).

In general, the contribution of intangible capital to labour productivity growth is positive, but this is not a universal finding. Sectors such as mining (CA and CB), textiles (17) and the manufacture of wood products (DD) experience a negative impact on growth in GVA per hour (in other words the intangible capital stock is declining in these sectors over this period). Looking at the right hand side of Table 5.3a we see that there is much heterogeneity in the contributions to labour productivity growth by intangible asset type. Higher technology sectors identified in Chapter 3 such as the manufacture of electrical machinery and medical and precision equipment (31 to 33) show significant contributions, most notably from R&D. This is also true for Chemicals (DG). Organisational capital has a relatively greater contribution to make in the manufacture of leather goods (DC) and in wearing apparel (18). The manufacture of rubber and plastics and non-metallic products also benefited from relatively substantial contributions from organisation capital. IT capital is more evenly spread with the exception of the manufacture of medical and precision equipment.

Considering now the later period in production, we see from Table 5.3b that the overall contribution from intangibles to labour productivity growth is positive. We only observe one or two small individual negative values (e.g. IT in non-metallic mineral products). Again, the most substantial contributions are made in medical and precision equipment and electrical equipment. R&D seems to be a particularly important source of labour productivity growth in this period. The lowest contributions are seen in the manufacture of wood products and paper, printing and publishing. Once again, there is a clear distinction between knowledge intensive, higher technology sectors and the mature manufacturing industries.

From Tables 5.3a and 5.3b we note very little visual correlation between sectors with high labour productivity growth and relatively large contributions from any particular form of intangible capital. Sector 32, the manufacture of TV, radio and communications equipment, is perhaps the most puzzling finding from the first period to the second period. In the early period, intangible capital is amongst the highest in manufacturing despite a negative labour productivity growth, however, by 2003-2006, labour productivity growth has become high but the relative contribution of intangibles to this is negative across the board. This might reflect the rapidly changing nature of the industry with the benefit from intangibles coming in the second period.

Table 5.3a: Growth accounting contributions for Production Sectors, 1998-2001

| SIC Code | | Sample size | adjusted - unadjusted GVA per hour growth | Growth in adjusted GVA per hour | Organisation capital | R&D | IT | All |
|---|---|---|---|---|---|---|---|---|
| CA | Mining and quarrying of energy producing materials | 126 | -0.14% | 13.02% | 0.15% | 0.33% | 0.03% | 0.52% |
| CB | Mining and quarrying except energy producing material | 122 | -0.27% | 0.26% | -0.06% | 0.00% | 0.02% | -0.05% |
| DA | Manufacture of food products; beverages and tobacco | 1,019 | 0.07% | 3.00% | 0.12% | 0.09% | 0.04% | 0.25% |
| 17 | Manufacture of textiles | 515 | -0.53% | 3.36% | 0.22% | -0.10% | 0.02% | 0.13% |
| 18 | Manufacture of wearing apparel; dressing and dyeing of fur | 253 | 0.28% | 7.25% | 0.42% | 0.22% | 0.01% | 0.66% |
| DC | Manufacture of leather and leather products | 92 | 0.00% | 11.97% | 0.46% | -0.01% | -0.10% | 0.35% |
| DD | Manufacture of wood and wood products | 291 | -0.69% | 1.78% | -0.12% | -0.24% | -0.02% | -0.37% |
| 21 | Manufacture of pulp, paper and paper products | 335 | -0.07% | 2.80% | 0.22% | -0.01% | 0.07% | 0.28% |
| 22 | Publishing, printing and reproduction of recorded media | 966 | 0.12% | 3.28% | 0.11% | 0.06% | 0.16% | 0.33% |
| DG | Manufac. of chemicals, chemical products and man-made fibres | 621 | -0.40% | 4.58% | 0.19% | 0.54% | 0.08% | 0.81% |
| DH | Manufacture of rubber and plastic products | 654 | 0.03% | 3.83% | 0.24% | 0.05% | 0.01% | 0.30% |
| DI | Manufacture of other non-metallic mineral products | 439 | 0.05% | 2.33% | 0.24% | -0.03% | -0.03% | 0.18% |
| 27 | Manufacture of basic metals | 389 | 0.30% | -0.24% | 0.01% | 0.19% | -0.05% | 0.15% |
| 28 | Manufacture of fabricated metal products, except M&Eq | 1,318 | -0.25% | 2.27% | 0.08% | 0.10% | 0.01% | 0.19% |
| DK | Manufacture of machinery and equipment n.e.c. | 1,102 | 0.50% | -0.04% | 0.10% | 0.55% | 0.03% | 0.68% |
| 30 | Manufacture of office machinery and computers | 112 | -2.13% | 6.54% | 0.47% | 0.51% | 0.65% | 1.63% |
| 31 | Manufacture of electrical machinery and apparatus n.e.c. | 463 | 0.05% | 5.58% | 0.18% | 0.91% | 0.07% | 1.16% |
| 32 | Manufacture of radio, television and communication equipment | 239 | 5.90% | -10.44% | 0.38% | 1.12% | 0.71% | 2.20% |
| 33 | Manufacture of medical, precision and optical instruments, etc | 400 | -0.31% | 3.66% | 0.10% | 0.60% | 0.37% | 1.07% |
| 34 | Manufacture of motor vehicles, trailers and semi-trailers | 335 | 0.36% | 3.04% | 0.22% | 1.19% | 0.10% | 1.51% |
| 35 | Manufacture of other transport equipment | 239 | -0.01% | 3.47% | 0.11% | 0.53% | -0.04% | 0.59% |
| 36 | Manufacture of furniture; manufacturing n.e.c. | 617 | 0.10% | 3.05% | 0.02% | 0.23% | 0.04% | 0.29% |
| 37 | Recycling | 59 | 0.00% | 3.86% | 0.19% | -0.04% | -0.06% | 0.10% |

**Table 5.3b: Growth accounting contributions for Production Sectors, 2003-2006**

| SIC Code | | no of firms | adjusted - unadjusted GVA per hour growth | Growth in adjusted GVA per hour | Organisation capital | R&D | IT | All |
|---|---|---|---|---|---|---|---|---|
| CA | Mining and quarrying of energy producing materials | 87 | 0.60% | -8.28% | 0.07% | 0.15% | 0.02% | 0.23% |
| CB | Mining and quarrying except energy producing material | 105 | 0.47% | 3.48% | 0.32% | 0.20% | 0.05% | 0.57% |
| DA | Manufacture of food products; beverages and tobacco | 892 | -0.03% | 3.53% | 0.04% | 0.14% | 0.03% | 0.21% |
| 17 | Manufacture of textiles | 393 | 0.09% | 4.51% | 0.15% | 0.14% | 0.02% | 0.31% |
| 18 | Manufacture of wearing apparel; dressing and dyeing of fur | 198 | -0.31% | 7.34% | 0.01% | 0.09% | 0.11% | 0.21% |
| DC | Manufacture of leather and leather products | 64 | 0.53% | -5.88% | 0.29% | -0.03% | -0.01% | 0.26% |
| DD | Manufacture of wood and wood products | 271 | -0.01% | 3.16% | -0.02% | 0.06% | 0.03% | 0.07% |
| 21 | Manufacture of pulp, paper and paper products | 274 | 0.33% | -3.32% | 0.10% | 0.17% | 0.04% | 0.30% |
| 22 | Publishing, printing and reproduction of recorded media | 833 | -0.03% | 2.60% | 0.11% | 0.05% | 0.01% | 0.17% |
| DG | Manufac. of chemicals, chemical products and man-made fibres | 537 | -0.69% | 6.69% | 0.19% | 0.48% | 0.00% | 0.66% |
| DH | Manufacture of rubber and plastic products | 588 | 0.11% | 1.97% | 0.11% | 0.09% | 0.01% | 0.21% |
| DI | Manufacture of other non-metallic mineral products | 376 | 0.18% | 3.42% | 0.09% | 0.13% | -0.01% | 0.21% |
| 27 | Manufacture of basic metals | 319 | -0.29% | 10.55% | 0.35% | 0.38% | 0.03% | 0.75% |
| DK | Manufacture of machinery and equipment n.e.c. | 930 | -0.36% | 4.64% | 0.05% | 0.38% | 0.12% | 0.55% |
| 28 | Manufacture of fabricated metal products, except M&Eq | 1,199 | 0.19% | 0.88% | 0.06% | 0.17% | 0.02% | 0.24% |
| 30 | Manufacture of office machinery and computers | 91 | -0.63% | 6.47% | -0.22% | -0.08% | -0.10% | -0.39% |
| 31 | Manufacture of electrical machinery and apparatus n.e.c. | 387 | -0.23% | 5.94% | 0.28% | 0.41% | 0.24% | 0.93% |
| 32 | Manufacture of radio, television and communication equipment | 220 | -3.28% | 14.84% | -0.25% | -0.58% | -0.30% | -1.13% |
| 33 | Manufacture of medical, precision and optical instruments, etc | 340 | -0.45% | 5.78% | 0.20% | 0.77% | 0.31% | 1.28% |
| 34 | Manufacture of motor vehicles, trailers and semi-trailers | 303 | -0.29% | 7.28% | 0.18% | 0.61% | 0.04% | 0.83% |
| 35 | Manufacture of other transport equipment | 214 | 0.57% | 0.60% | 0.03% | 0.73% | 0.04% | 0.80% |
| 36 | Manufacture of furniture; manufacturing n.e.c. | 595 | 0.06% | 3.58% | 0.26% | 0.07% | 0.07% | 0.40% |
| 37 | Recycling | 64 | -0.11% | 11.79% | 0.00% | 0.36% | -0.12% | 0.24% |

**Table 5.4a: Services growth accounting results, 1998-2001**

| SIC Code | | Sample size | adjusted - unadjusted GVA per hour growth | Growth in adjusted GVA per hour | Organisation capital | R&D | IT | All |
|---|---|---|---|---|---|---|---|---|
| E | Electricity, gas and water supply | 67 | -0.45% | -2.33% | -0.04% | 0.11% | 0.05% | 0.13% |
| F | Construction | 2,992 | 0.39% | 3.08% | 0.28% | 0.27% | 0.01% | 0.56% |
| 50 | Sale, maintenance & repair of motor vehicles; retail sale of fuel | 2,061 | 0.12% | 2.19% | 0.10% | 0.05% | 0.03% | 0.18% |
| 51 | Wholesale trade & commission trade, except of motor vehicles & motorcycles | 4,719 | 0.13% | 0.77% | 0.05% | 0.05% | 0.18% | 0.27% |
| 52 | Retail trade, except ...; repair of personal & household goods | 5,093 | 0.14% | 2.00% | 0.11% | 0.14% | 0.00% | 0.25% |
| H | Hotels and restaurants | 2,584 | 0.14% | 2.72% | 0.34% | 0.00% | -0.01% | 0.33% |
| 60 | Land transport; transport via pipelines | 904 | -0.04% | 0.56% | 0.04% | 0.01% | -0.02% | 0.03% |
| 61 | Water transport | 74 | -0.51% | 3.84% | -0.02% | 0.03% | 0.18% | 0.18% |
| 62 | Air transport | 60 | -0.08% | 10.15% | 0.17% | 0.16% | 0.01% | 0.35% |
| 63 | Supporting & auxiliary transport activities; activities of travel agencies | 804 | 0.39% | 1.00% | 0.17% | 0.04% | 0.09% | 0.31% |
| 64 | Post and telecommunications | 206 | -3.65% | 10.78% | 0.04% | -0.26% | 0.07% | -0.15% |
| 71 | Renting of machinery & equipment without operator & of personal & household | 384 | 0.20% | -0.44% | 0.14% | 0.05% | 0.04% | 0.24% |
| 72 | Computer and related activities | 1,076 | 0.84% | 0.74% | 0.43% | 0.03% | 1.04% | 1.50% |
| 73 | Research and development | 115 | 0.60% | 0.57% | 0.23% | 2.22% | 0.31% | 2.76% |
| 74 | Other business activities | 4,813 | -0.17% | 2.21% | 0.18% | 0.22% | 0.02% | 0.41% |
| M | Education | 834 | 2.14% | -9.54% | 0.16% | -0.34% | 0.27% | 0.09% |
| N | Health and social work | 1,364 | 0.19% | 0.68% | 0.02% | 1.12% | 0.04% | 1.17% |
| 90 | Sewage and refuse disposal, sanitation and similar activities | 98 | -0.19% | -9.39% | -0.08% | -0.26% | 0.01% | -0.33% |
| 91 | Activities of membership organization n.e.c. | 493 | 1.98% | -11.64% | 0.52% | 0.33% | -0.15% | 0.69% |
| 92 | Recreational, cultural and sporting activities | 1,084 | 0.31% | 2.85% | 0.22% | 0.03% | 0.04% | 0.29% |
| 93 | Other services activities | 787 | -0.29% | 7.08% | 0.13% | -0.07% | 0.03% | 0.09% |

### Table 5.4b: Services growth accounting results, 2003-2006

| SIC Code | | no of firms | adjusted - unadjusted GVA per hour growth | Growth in adjusted GVA per hour | Organisation capital | R&D | IT | All |
|---|---|---|---|---|---|---|---|---|
| E | Electricity, gas and water supply | 51 | 0.26% | 1.70% | 0.09% | 0.24% | -0.05% | 0.28% |
| F | Construction | 3,063 | 0.24% | 0.94% | 0.07% | 0.16% | 0.02% | 0.25% |
| 50 | Sale, maintenance & repair of motor vehicles; retail sale of fuel | 1,825 | 0.05% | 1.74% | 0.02% | 0.13% | 0.04% | 0.19% |
| 51 | Wholesale trade & commission trade, except of motor vehicles & motorcycles | 4,247 | 0.00% | 6.04% | 0.22% | 0.19% | 0.19% | 0.60% |
| 52 | Retail trade, except ...; repair of personal & household goods | 4,647 | -0.15% | 5.08% | 0.18% | 0.02% | 0.00% | 0.20% |
| H | Hotels and restaurants | 2,435 | -0.02% | 1.50% | 0.08% | 0.04% | 0.00% | 0.11% |
| 60 | Land transport; transport via pipelines | 878 | 0.02% | 1.54% | 0.00% | -0.01% | 0.02% | 0.01% |
| 61 | Water transport | 78 | 0.18% | 3.56% | 0.29% | 0.04% | 0.08% | 0.41% |
| 62 | Air transport | 50 | 0.40% | -1.10% | -0.24% | -0.08% | 0.11% | -0.22% |
| 63 | Supporting & auxiliary transport activities; activities of travel agencies | 782 | -0.18% | 7.85% | 0.17% | 0.11% | -0.01% | 0.27% |
| 64 | Post and telecommunications | 240 | -1.87% | 9.06% | -0.14% | -0.46% | -0.14% | -0.74% |
| 71 | Renting of machinery & equipment without operator & of personal & household | 392 | 0.00% | 0.60% | 0.01% | 0.02% | -0.01% | 0.02% |
| 72 | Computer and related activities | 1,032 | -0.63% | 6.22% | 0.06% | 0.08% | 1.01% | 1.16% |
| 73 | Research and development | 118 | -2.93% | 6.04% | 0.17% | 1.99% | 0.42% | 2.58% |
| 74 | Other business activities | 4,644 | -0.19% | 4.16% | 0.21% | 0.28% | 0.05% | 0.54% |
| M | Education | 926 | -0.06% | 3.81% | 0.54% | 0.05% | 0.23% | 0.82% |
| N | Health and social work | 1,353 | -0.15% | 0.90% | 0.06% | 0.24% | 0.01% | 0.31% |
| 90 | Sewage and refuse disposal, sanitation and similar activities | 115 | -0.21% | 1.90% | 0.05% | 0.07% | 0.00% | 0.12% |
| 91 | Activities of membership organization n.e.c. | 477 | -0.25% | 6.38% | 0.63% | 0.27% | -0.06% | 0.85% |
| 92 | Recreational, cultural and sporting activities | 1,103 | 1.11% | -5.60% | 0.44% | 0.04% | -0.02% | 0.47% |
| 93 | Other services activities | 795 | -0.13% | 1.74% | 0.04% | -0.06% | -0.01% | -0.03% |

Tables 5.4a and b repeat the periods above for construction and service sectors. Once again, we shade values according to their relative magnitude. The shading suggests a more modest contribution to labour productivity growth than in manufacturing sectors, across both periods. The key exceptions to this are sectors 72 and 73, computing services and R&D activities. This is true for both periods. In Table 5.4a, negative contributions from combined intangibles are seen in the following sectors; sewage and refuse disposal and post and telecommunications (in these sectors, the negative effect is driven by R&D, i.e. R&D capital is falling). Intangibles are important for the following sectors; health and social work (N), research and development (73) and computer and related activities (72). Organisation capital is important in activities of membership organisations (91), computer and related activities (72) and hotels and restaurants (H) but negative in water transport (61) and sewage and refuse disposal (90).

If we want to consider the second period, we see that whilst there is considerable change in the contributions by sector, those that have the largest contributions from intangibles remain the same research and development (73) and computer and related activities (72). Interestingly post and telecommunication experiences a negative contribution from all intangible assets during the period 2003-2006; the only sector to do so.

One thing to note about the approach taken is that it does not offer any judgement on the relative importance of the sectors. Thus, we find that organisation capital is important in sector 91, however we know this to be a relatively small component of overall services in the UK (see Table 3.3). It is worth bearing this in mind when considering the findings.

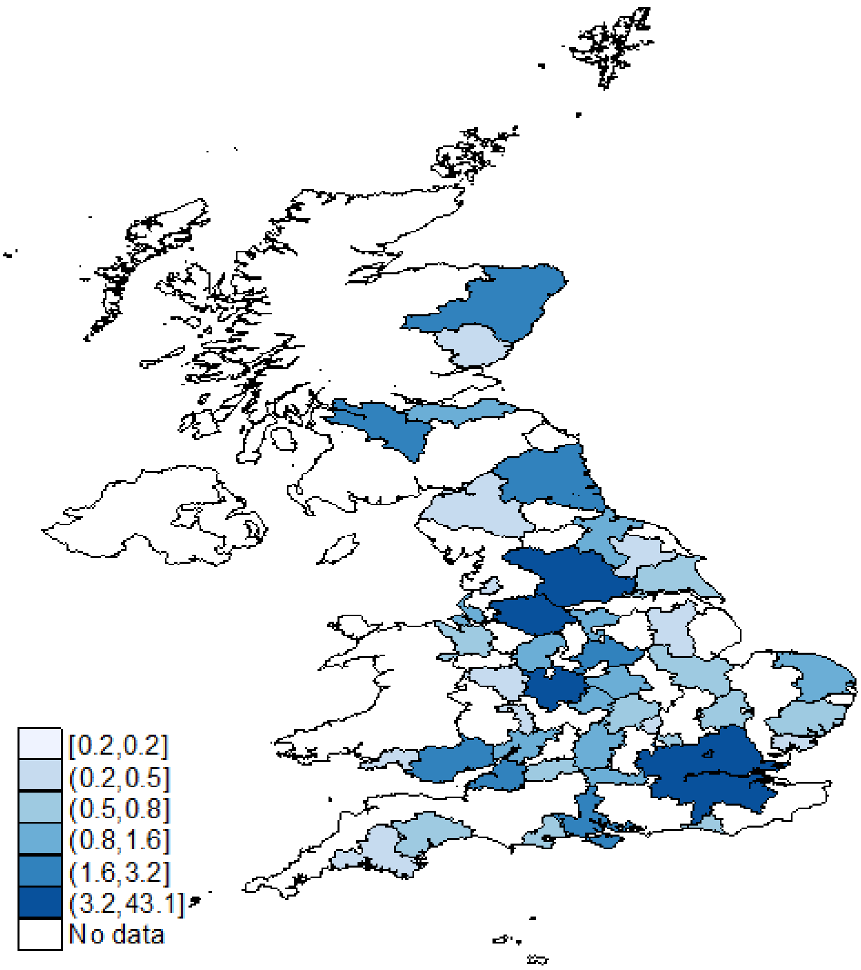
## 5.3 The contribution of intangible capital to productivity growth in City Regions

**As well as a sectoral understanding, it is useful to see where in the UK the role of intangible capital is affecting labour productivity growth. Here we present growth accounts by city region. Our findings indicate that whilst there is some persistence in the first half of our period (1998-2001) across the various intangible assets, particularly from southern city regions, the second half of the period (2003-2006) reveals different city regions are experiencing large impacts on labour productivity growth.**

As well as establishing which sectors are most likely to have high (or indeed low) levels of intangible capital and which sectors see positive effects from their contribution to labour productivity growth, we are also interested in which regions experience similar benefits. Therefore, a growth accounting exercise was conducted using regional data rather than sector data. As previously discussed, our geography of choice was not administratively defined but adopted the city region classification developed by Robson et al (2006).

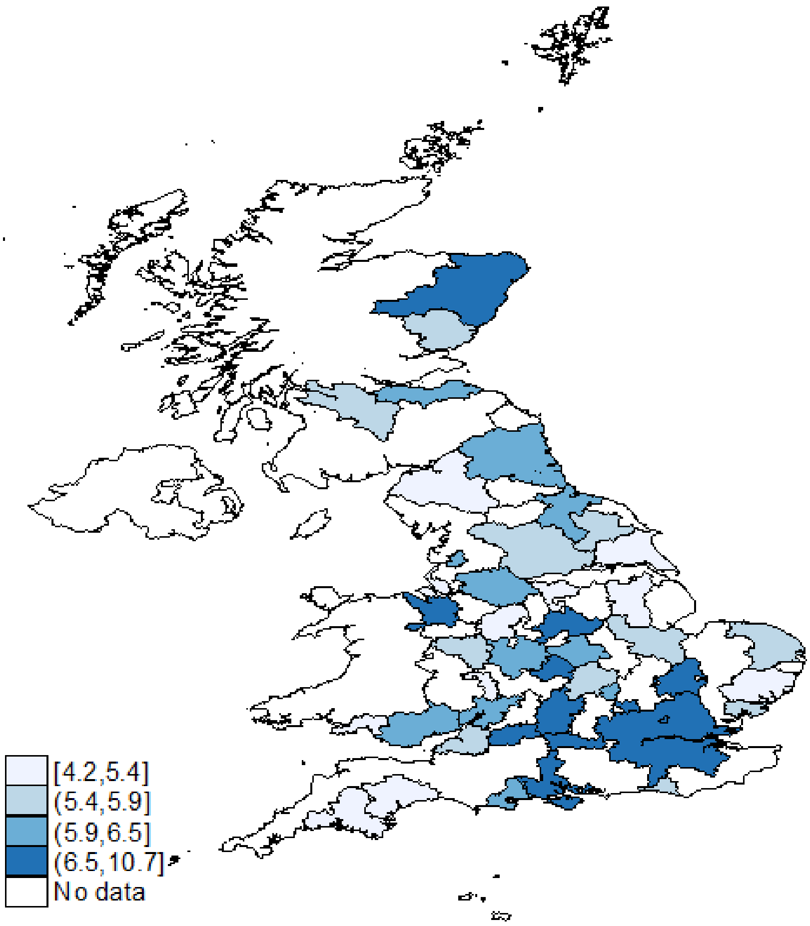
Figure 5.2 shows the regional distribution of UK intangible capital. Unsurprisingly, there are concentrations in the Greater London area, Birmingham and in the Manchester and Leeds areas. These are consistent with major conurbations and where we would expect to see more of most activities. Figure 5.3 presents the intensity of intangible capital, dividing the shares through by hours worked. While this looks similar, there are notable differences. For example, the Leeds City Region appears to have a large share of overall intangible capital, but the concentration of intangible capital there appears less when measured per hour worked.

**Figure 5.2: Regional shares of national intangible capital (%)**




Notes: Non-farm business sector excluding finance, construction, utilities; 1998-2006 average

**Figure 5.3: Intangible capital per hour worked (£)**




Notes: Non-farm business sector excluding finance, construction, utilities; 1998-2006 average

In Tables 5.5 and 5.6 below we show the results on the contribution of intangible assets to labour productivity growth using the same periods as before, 1998-2001 and 2003-2006.

In Table 5.5 overall, most city regions experience a positive contribution to labour productivity growth from intangible capital. Adjusted labour productivity growth is highest in Northampton, Oxford, Swindon, Worcester and Reading. Regions experiencing negative contribution to labour productivity growth include Cardiff, Worcester, Glasgow, Luton, Liverpool and Preston. These are not the least densely populated city regions and the source of the negative impact varies between R&D or in the more densely populated regions, organisation capital. There is substantial diversity in the contributions that intangibles make to labour productivity growth. Negative impacts from organisational capital appear to be more common in the less populated city regions (i.e. organisation capital is declining in the less populated city regions).

Table 5.6 covers the same regions for the period 2003-2006. Adjusted labour productivity growth is highest here for Peterborough and Swansea. The contribution of R&D appears to be generally the most important, although there are a number of city regions where organisation capital is relatively larger (c.f. York or Cheltenham and Gloucester). Overall, intangibles contribute most to labour productivity growth in Brighton and Hove, Lincoln and Manchester/Salford/Trafford.

**Table 5.5: Contributions to labour productivity growth by city region 1998-2001 (shaded largest to smallest)**

| City Region | No of firms | Adjusted - unadjusted GVA p.h. growth | Growth in adjusted GVA per hour | Organisation capital | R&D | IT | All |
|---|---|---|---|---|---|---|---|
| Reading | 341 | -2.62% | 19.10% | 0.10% | 0.34% | 0.53% | 0.98% |
| Northampton | 332 | -2.22% | 12.22% | 0.10% | -0.05% | 0.04% | 0.10% |
| Worcester | 120 | -1.67% | 11.97% | -0.28% | -0.11% | 0.20% | -0.19% |
| Swindon | 211 | -1.06% | 10.84% | -0.03% | 0.09% | 0.10% | 0.17% |
| Oxford | 371 | 2.16% | 9.67% | 0.23% | 1.51% | 0.14% | 1.89% |
| Chester | 250 | -1.39% | 7.29% | 0.11% | 0.33% | 0.02% | 0.46% |
| Middlesborough/Stockton | 373 | -0.99% | 6.85% | 0.13% | 0.50% | 0.15% | 0.78% |
| Brighton/Hove | 247 | -0.40% | 6.72% | 0.32% | 0.74% | 0.16% | 1.22% |
| Milton Keynes | 171 | -0.61% | 5.73% | 0.07% | 0.00% | 0.12% | 0.20% |
| Ipswich | 292 | -0.92% | 5.72% | 0.17% | 0.07% | 0.01% | 0.25% |
| Preston | 178 | -1.47% | 5.47% | -0.10% | 0.12% | -0.10% | -0.08% |
| Lincoln | 162 | 0.58% | 5.00% | 0.38% | 0.19% | 0.19% | 0.76% |
| Aberdeen | 672 | 0.10% | 4.92% | 0.10% | 0.41% | 0.01% | 0.52% |
| Colchester | 168 | -0.05% | 4.01% | 0.25% | 0.20% | 0.08% | 0.53% |
| Exeter | 291 | -0.19% | 3.16% | 0.32% | 0.20% | 0.09% | 0.62% |
| Leeds/Bradford | 1,741 | 0.47% | 3.15% | 0.20% | 0.34% | 0.16% | 0.69% |
| Norwich | 404 | 1.67% | 3.14% | 0.14% | 0.72% | 0.13% | 0.99% |
| Newcastle/Gates/Sund | 877 | 0.86% | 2.77% | 0.15% | 0.53% | 0.20% | 0.88% |
| Kingston upon Hull | 362 | 0.03% | 2.59% | 0.11% | 0.17% | 0.11% | 0.38% |
| Bristol/S. Glouc | 657 | 0.39% | 2.57% | 0.06% | 0.15% | 0.14% | 0.35% |
| Manchester/Salford/Trafford | 2,017 | -0.63% | 2.50% | 0.12% | 0.27% | 0.07% | 0.46% |
| Plymouth | 249 | 2.15% | 1.21% | 0.10% | 0.90% | 0.12% | 1.12% |
| Swansea | 144 | 0.49% | 1.21% | 0.15% | 0.25% | 0.04% | 0.44% |
| Greater London | 8,536 | -0.26% | 1.07% | 0.09% | 0.09% | 0.17% | 0.35% |
| Leicester | 622 | 0.51% | 0.86% | 0.17% | 0.33% | 0.08% | 0.57% |
| Carlisle | 181 | 0.56% | 0.63% | 0.18% | 0.20% | 0.04% | 0.42% |
| Cambridge | 240 | -0.55% | 0.31% | -0.01% | 0.07% | 0.27% | 0.34% |
| Telford and Wrekin | 211 | 0.89% | 0.28% | 0.18% | 0.41% | 0.13% | 0.71% |
| Sheffield | 523 | 0.13% | -0.25% | 0.15% | 0.10% | 0.03% | 0.28% |
| Stoke on Trent | 368 | 0.93% | -0.40% | 0.15% | 0.27% | 0.30% | 0.71% |
| York | 163 | 1.07% | -0.45% | -0.01% | 0.38% | -0.01% | 0.36% |
| Portsmouth/Southampton | 759 | 0.98% | -0.48% | 0.09% | 0.23% | 0.25% | 0.57% |
| Birm/Sand/Wolver | 1,975 | 0.07% | -0.49% | 0.03% | 0.34% | 0.11% | 0.48% |
| Notts/Derby | 839 | 0.49% | -0.67% | 0.16% | 0.56% | 0.05% | 0.77% |
| Dundee | 217 | -0.54% | -1.32% | 0.01% | 0.30% | 0.09% | 0.40% |
| Coventry | 407 | -0.08% | -1.40% | 0.07% | 0.29% | 0.12% | 0.48% |

**Table 5.5 continued: Contributions to labour productivity growth by city region 1998-2001 (shaded largest to smallest)**

| City Region | No of firms | Adjusted - unadjusted GVA p.h. growth | Growth in adjusted GVA per hour | Organisation capital | R&D | IT | All |
|---|---|---|---|---|---|---|---|
| Edinburgh | 701 | 0.33% | -1.86% | -0.12% | 0.28% | 0.16% | 0.32% |
| Liverpool | 541 | -0.27% | -2.38% | -0.21% | 0.00% | 0.04% | -0.17% |
| Bournemouth/Poole | 342 | 0.04% | -2.88% | 0.06% | 0.33% | 0.26% | 0.64% |
| Peterborough | 309 | 0.74% | -2.89% | -0.12% | 0.14% | 0.40% | 0.43% |
| Glasgow | 1,358 | 0.04% | -5.31% | -0.14% | 0.06% | -0.01% | -0.08% |
| Glouc/Chelt | 343 | 1.47% | -6.73% | 0.09% | 0.25% | 0.05% | 0.39% |
| Luton | 158 | -0.30% | -7.49% | 0.03% | -0.08% | -0.05% | -0.10% |
| Cardiff | 958 | 0.30% | -8.59% | -0.03% | -0.17% | 0.00% | -0.19% |

**Table 5.6: Contributions to labour productivity growth by city region 2003-2006 (shaded largest to smallest)**

| City Region | no of firms | adjusted - unadjusted GVA per hour growth | Growth in adjusted GVA per hour | Organisation capital | R&D | IT | All |
|---|---|---|---|---|---|---|---|
| Peterborough | 303 | -0.70% | 14.08% | 0.14% | 0.65% | 0.15% | 0.93% |
| Swansea | 356 | -0.27% | 10.22% | 0.30% | 0.37% | 0.15% | 0.82% |
| Leicester | 746 | -0.23% | 7.99% | 0.15% | 0.42% | 0.05% | 0.61% |
| Dundee | 328 | -0.43% | 7.82% | 0.23% | 0.28% | 0.26% | 0.77% |
| Swindon | 762 | -1.80% | 7.35% | 0.00% | -0.18% | -0.02% | -0.20% |
| Norwich | 176 | 0.17% | 6.46% | 0.33% | 0.29% | 0.07% | 0.68% |
| Greater London | 633 | -0.87% | 6.00% | 0.31% | 0.26% | 0.10% | 0.66% |
| Coventry | 323 | -0.35% | 5.98% | 0.28% | 0.28% | 0.25% | 0.82% |
| Glasgow | 293 | -1.00% | 5.78% | 0.05% | 0.19% | -0.23% | 0.01% |
| Liverpool | 1,216 | -0.25% | 5.51% | 0.11% | 0.18% | 0.23% | 0.52% |
| Worcester | 309 | -0.87% | 5.29% | 0.28% | -0.10% | 0.06% | 0.24% |
| Telford and Wrekin | 358 | -1.23% | 4.92% | -0.11% | 0.03% | -0.05% | -0.13% |
| Edinburgh | 348 | -0.30% | 4.82% | 0.07% | 0.30% | 0.51% | 0.88% |
| Leeds/Bradford | 498 | 0.43% | 3.76% | 0.13% | 0.25% | 0.31% | 0.68% |
| Brighton/Hove | 716 | 1.06% | 3.34% | 0.12% | 0.45% | 0.71% | 1.28% |
| York | 291 | -0.64% | 2.88% | 0.19% | 0.03% | 0.02% | 0.24% |
| Cardiff | 349 | 0.70% | 2.87% | 0.29% | 0.65% | 0.06% | 1.00% |
| Aberdeen | 7,786 | -0.20% | 2.75% | 0.10% | 0.07% | 0.11% | 0.28% |
| Northampton | 1,736 | -0.21% | 2.51% | 0.16% | 0.23% | -0.19% | 0.19% |
| Reading | 115 | 0.66% | 2.48% | 0.10% | 0.33% | 0.39% | 0.82% |
| Carlisle | 1,666 | 0.06% | 2.32% | 0.14% | 0.11% | 0.11% | 0.36% |
| Exeter | 307 | -0.67% | 2.11% | 0.09% | -0.02% | -0.22% | -0.15% |
| Manchester/Salford/Trafford | 204 | 0.46% | 1.86% | 0.13% | 0.73% | 0.27% | 1.12% |
| Bristol/S. Glouc | 157 | 0.27% | 1.69% | 0.20% | 0.15% | 0.05% | 0.39% |
| Glouc/Chelt | 147 | 0.01% | 1.67% | 0.51% | 0.10% | 0.12% | 0.73% |
| Bournemouth/Poole | 233 | 0.51% | 1.66% | 0.15% | 0.38% | 0.00% | 0.53% |
| Luton | 1,298 | -0.82% | 1.65% | -0.02% | -0.04% | 0.12% | 0.06% |
| Lincoln | 242 | 1.65% | 1.58% | 0.06% | 0.80% | 0.28% | 1.14% |
| Sheffield | 151 | 0.66% | 1.56% | 0.14% | 0.30% | 0.20% | 0.63% |
| Portsmouth/Southampton | 200 | 0.35% | 1.49% | 0.22% | 0.35% | 0.06% | 0.64% |
| Middlesborough/Stockton | 470 | -0.24% | 1.18% | 0.30% | -0.15% | -0.04% | 0.12% |
| Chester | 1,570 | 0.42% | 1.16% | 0.06% | 0.22% | 0.09% | 0.37% |
| Stoke on Trent | 156 | -0.44% | 1.09% | 0.05% | -0.12% | 0.07% | 0.00% |
| Oxford | 361 | -0.44% | 0.71% | -0.04% | -0.02% | 0.02% | -0.04% |
| Preston | 194 | -0.63% | 0.47% | 0.08% | -0.21% | -0.08% | -0.20% |
| Colchester | 515 | -0.05% | 0.36% | 0.11% | 0.05% | 0.01% | 0.17% |
| Milton Keynes | 334 | -0.79% | 0.36% | 0.02% | -0.14% | 0.03% | -0.09% |
| Birm/Sand/Wolver | 571 | 0.43% | 0.19% | 0.11% | 0.20% | 0.01% | 0.33% |

**Table 5.6 continued: Contributions to labour productivity growth by city region 2003-2006 shaded largest to smallest)**

| City Region | no of firms | adjusted - unadjusted GVA per hour growth | Growth in adjusted GVA per hour | Organisation capital | R&D | IT | All |
|---|---|---|---|---|---|---|---|
| Plymouth | 162 | -0.20% | 0.13% | 0.00% | 0.82% | 0.02% | 0.84% |
| Notts/Derby | 183 | 0.79% | -0.72% | 0.15% | 0.33% | 0.24% | 0.72% |
| Kingston upon Hull | 606 | -0.17% | -0.83% | 0.11% | -0.05% | 0.01% | 0.07% |
| Newcastle/Gates/Sund | 156 | -0.23% | -3.76% | 0.16% | -0.20% | 0.07% | 0.03% |
| Ipswich | 225 | 2.55% | -5.33% | -0.01% | 0.75% | 0.25% | 0.98% |
| Cambridge | 284 | 1.33% | -5.73% | -0.01% | 0.28% | 0.00% | 0.27% |

Given that the degree of correlation between the various forms of intangible capital is not immediately apparent, Table 5.7 contains a simple correlation matrix for the coefficients in the two periods, for production and services separately. There are a few things to note; in all cases, the correlations are positive, in the case of production, the correlations appear to be relatively strong, compared with services, which seem less correlated (a reflection no doubt of the heterogeneity in this sector more generally). It is also clear that the correlations do not appear all that stable over time, particularly amongst service sectors.

**Table 5.7: Correlations between intangible capital contributions to labour productivity growth**

| | production 1998-2001 | | | production 2003-2006 | | | services 1998-2001 | | | services 2003-2006 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | org | R&D | IT | org | R&D | IT | org | R&D | IT | org | R&D | IT |
| organisation capital | 1.00 | 0.26 | 0.40 | 1.00 | 0.48 | 0.59 | 1.00 | 0.15 | 0.27 | 1.00 | 0.20 | 0.01 |
| R&D capital | | 1.00 | 0.55 | | 1.00 | 0.68 | | 1.00 | 0.08 | | 1.00 | 0.33 |
| IT capital | | | 1.00 | | | 1.00 | | | 1.00 | | | 1.00 |

## 5.4 Summary and Conclusions

In this Chapter, we have presented a great deal of information on the contributions intangibles make to sector level and regional level performance, measured in terms of labour productivity growth. Table 5.8 summarises our findings by listing sectors that have experienced the highest intangibles contributions by asset type. Table 5.9 does the same in relation to city regions. There appears to be much more persistence in the contribution of intangibles to industries than there is to regions.

## Table 5.8: Top 5 Sectors by Intangible Contributions, 1998-2001 and 2003-2006

| Organisation Capital | R&D | IT | All |
|---|---|---|---|
| **PRODUCTION (1998-2001)** | | | |
| Manufacture of leather and leather products (DC) | Manufacture of motor vehicles, trailers and semi-trailers (34) | Manufacture of medical, precision and optical instruments, watches & clocks (33) | Manufacture of motor vehicles, trailers and semi-trailers (34) |
| Manufacture of wearing apparel; dressing and dyeing of fur (18) | Manufacture of electrical machinery and apparatus n.e.c. (31) | Printing and publishing (22) | Manufacture of electrical machinery and apparatus n.e.c. (31) |
| Rubber and plastics (DH) | Manufacture of medical, precision and optical instruments, watches & clocks (33) | Manufacture of motor vehicles, trailers and semi-trailers (34) | Manufacture of medical, precision and optical instruments, watches & clocks (33) |
| Other non-metallic products (DI) | Machinery and equipment (DK) | Manufac. of chemicals, chemical products and man-made fibres (DG) | Manufac. of chemicals, chemical products and man-made fibres (DG) |
| Textiles (17) | Manufac. of chemicals, chemical products and man-made fibres (DG) | Manufacture of electrical machinery and apparatus n.e.c. (31) | Machinery and equipment (DK) |
| **PRODUCTION (2003-2006)** | | | |
| Manufacture of basic metals (27) | Manufacture of medical, precision and optical instruments, watches & clocks (33) | Manufacture of medical, precision and optical instruments, watches & clocks (33) | Manufacture of medical, precision and optical instruments, watches & clocks (33) |
| Mining and quarrying except energy producing material (CB) | Manufacture of other transport equipment (35) | Manufacture of electrical machinery and apparatus n.e.c. (31) | Manufacture of electrical machinery and apparatus n.e.c. (31) |
| Manufacture of leather and leather products (DC) | Manufacture of motor vehicles, trailers and semi-trailers (34) | Manufacture of machinery and equipment n.e.c. (DK) | Manufacture of motor vehicles, trailers and semi-trailers (34) |
| Manufacture of electrical machinery and apparatus n.e.c. (31) | Manufac. of chemicals, chemical products and man-made fibres (DG) | Manufacture of wearing apparel; dressing and dyeing of fur (18) | Manufacture of other transport equipment (35) |
| Manufacture of furniture; manufacturing n.e.c. (36) | Manufacture of machinery and equipment n.e.c. (DK) | Manufacture of furniture; manufacturing n.e.c. (36) | Manufacture of basic metal (27) |
| **SERVICES (1998-2001)** | | | |
| Activities of membership organisations (91) | Research and Development (73) | Computer and related activities (72) | Research and Development (73) |
| Computer and related activities (72) | Health and social work (N) | Research and Development (73) | Computer and related activities (72) |
| Hotels and restaurants (H) | Activities of membership organisations (91) | Education (M) | Health and social work (N) |
| Construction (F) | Construction (F) | Wholesale (51) | Activities of membership organisations (91) |
| Research and Development (73) | Other business activities (74) | Water transport (61) | Construction (F) |
| **SERVICES (2003-2006)** | | | |
| Activities of membership organization n.e.c. (91) | Research and development (73) | Computer and related activities (72) | Research and development (73) |
| Education (M) | Other business activities (74) | Research and development (73) | Computer and related activities (72) |
| Recreational, cultural and sporting activities (92) | Activities of membership organization n.e.c. (91) | Education (M) | Activities of membership organization n.e.c. (91) |
| Water transport (61) | Electricity, gas and water supply (E) | Wholesale trade & commission trade, except of motor vehicles & motorcycles (51) | Education (M) |

| | | | |
|---|---|---|---|
| Wholesale trade & commission trade, except of motor vehicles & motorcycles (51) | Health and social work (N) | Air transport (62) | Wholesale trade & commission trade, except of motor vehicles & motorcycles (51) |

Looking firstly at Table 5.8 it is apparent that there is considerable overlap in industries that see significant contributions to labour productivity growth from various intangible inputs. In other words, industries with strong labour productivity contributions from one type of intangible capital tend to have strong labour productivity contributions from other types of intangible capital. Taking production, organisation capital is less obviously associated with higher technology industries. This is consistent with an argument that in more mature industries, intangible contributions are most likely to stem from the way things are managed and marketed rather than the innovation of new products and processes. If we consider services, there is again some evidence of overlap in industries that see significant contributions to labour productivity growth from various intangible inputs. The more knowledge intensive sectors rank highly in terms of contributions to labour productivity growth from R&D and IT capital. In the case of organisation capital, the sectors are more mixed.

Table 5.9 considers regions that have relatively higher contributions from intangible capital to labour productivity growth. We note that again there is some evidence of persistence across intangible capital types, Oxford and Brighton and Hove appear in two of the three asset types in the earlier period. However, when we move to consider the second time period, we see that Telford and Preston experience a similar display with respect to two out of the three intangible assets. It is perhaps interesting to note that the largest conurbations (Greater London, Liverpool, Manchester and Birmingham) do not always appear to benefit the most from intangible investments. Rather, the regions in Table 5.9 are more frequently the relatively wealthy, well connected regions, often (although not exclusively) within the South/M4 corridor (Reading and Oxford).

A final question to ask is how our findings compare to those of others. In the case of city regional analysis of intangibles, we know of no other published work in this area that uses a similarly constructed measure of intangibles over a similar geography for the UK. With respect to sectoral growth accounts that include intangibles we are able to compare with aggregate studies that contain results for the UK by Jona-Lasinio et al (2011) and at the sector level with Haskel et al (2011). In their top-down approach using national account type data Jona-Lasinio et al (2011) also find for the UK that economic competences (organisation capital) is the strongest component of intangible capital, as we find here. Interestingly, they note this is in contrast to other European nations such as Finland, where R&D has a much more prominent role to play.

**Table 5.9: Top 5 City Regions by Intangible Contributions, 1998-2001 and 2003-2006**

| **Organisation Capital** | **R&D** | **IT** | **All** |
|---|---|---|---|
| **1998-2001** | | | |
| Lincoln | Oxford | Reading | Oxford |
| Brighton and Hove | Plymouth | Peterborough | Brighton/Hove |
| Exeter | Brighton/ Hove | Stoke on Trent | Plymouth |
| Colchester | Norwich | Cambridge | Norwich |
| Oxford | Nottingham and Derby | Bournemouth and Poole | Reading |
| **2003-2006** | | | |
| Glouc/Chelt | Plymouth | Brighton/Hove | Brighton/Hove |
| Norwich | Lincoln | Edinburgh | Lincoln |
| Greater London | Ipswich | Reading | Manchester/Salford/ Trafford |
| Swansea | Manchester/Salford/ Trafford | Leeds/Bradford | Cardiff |
| Middlesborough/ Stockton | Cardiff | Lincoln | Ipswich |

Haskel et al (2011) present a number of growth accounting findings by sectors. Whilst their sectoral breakdown is not as disaggregated as ours, we are able to crudely compare manufacturing, for example, for a similar time period. For 1995-2007, Haskel et al (2011) see a contribution to labour productivity growth of around 0.5 per cent per annum. This compares with an unweighted average figure across our manufacturing sectors of 0.59 per cent 1998-2001 and 0.34 per cent for 2003-2006. Across business services, Haskel et al (2011) report a figure of 0.54 per cent per annum, compared with 1.23 per cent for the 1998-

2001 period and 1.08 per cent for the 2003-2006 period in our study. In the case of Retail, hotels and transport, we find the Haskel et al figure of around 0.24 per cent compares quite well with our estimates of around 0.19 for the 1998-2001 period and 0.20 for 2003-2006. Thus, our measures are similar in some instances, comparing better for aggregate measures for manufacturing than services. There are also some important caveats to highlight, not least the fact that our measure focuses on own account intangibles and does not include purchased intangibles. The exclusion of purchased intangibles means that our estimates may provide a lower bound to the level of intangible capital. It is unclear how this might affect the growth accounting results.

# 6. Conclusion

In this report we provide details on the measurement and construction of intangible capital stock es timates for UK firms using information on the wages and numbers of workers in key intangible occupations. We build on existing work on UK intangibles (Riley and Robinson, 2011a) in a number of ways. We cover specifically own account intangible capital stock, not that purchased in the market. Our measure is firm based which gives us considerable flexibility in aggregation either by sector or by geography. This research has been motivated by the increasing appreciation of the importance of knowledge in driving economic progress.

Having constructed new measures of intangible capital, our estimates have been incorporated into production function estimates and growth accounts to explore the association between intangibles and productivity, both in terms of levels and growth. We explore these associations at the firm, industry and regional level in order to improve our understanding of how intangibles interact with productivity.

The questions we posed at the outset were:

- How have intangible rich occupations evolved over time in the UK?
- Has their evolution varied substantially by industry or region (or country)?
- What contributions do these occupations make to productivity and growth?
- How do the spatial and industrial patterns of dispersion affect performance?

In terms of the first question, we have firstly defined intangible occupations and as part of our robustness checks, considered in detail the composition of our categories. In Chapter 3 we provide an overview of recent trends in intangible assets as defined by occupations. We note that in general, those in intangible occupations receive higher wages than others. The intangible data are not strictly comparable pre and post 2002 because of a break in the occupational coding. We are not able to say whether changes between the two periods are a result of changes in definitions or genuine changes in the use of intangible workers. We note that broadly the series seem comparable across the full period. It is evident that the composition of intangibles varies across sectors and this is particularly the case for R&D intangibles which are more sectorally concentrated than IT and organisational capital.

There is an increasingly widely held belief that the impact of intangibles on firm performance is positive and our results support this. By separating the effects into IT, R&D and organisational capital we can better understand where the drivers of productivity lie. Our findings highlight the importance of organisational capital particularly. When we look at the overall firm level estimates, we see that all types of intangible capital have a positive and significant association with productivity, and this finding is not sensitive to the inclusion of a number of control variables, including the average hourly wage per firm to proxy for labour quality (higher wages indicating a higher quality employee). By sector, our results for individual intangible capital sources differ. R&D in particular is found to be insignificant in a number of sectors in some specifications.

In our city region analysis, we find that intangible capital contributes positively to labour productivity growth in the majority of the 44 city regions in both periods, 1998-2001 and 2002-2006. Within each city region, the contributions from the three categories of intangible inputs varied and we noted more variation over time than was observed in the industry growth accounting exercise. We find that regions with the greatest contributions to labour productivity growth from intangible capital were not the major conurbations and industrial heartlands but relatively affluent, cities and towns known perhaps for their strong knowledge base (Oxford, Cambridge, Brighton, Norwich) and having relatively good communications.

The analysis presented in this report provides an initial exploration of the relationships between intangible assets and economic performance in the UK. Further research is needed to move from associations between intangibles and performance to establishing more robust, causal relationships between the two. Finding appropriate instruments is a well documented problem with production function estimation, but with more extensive data, more sophisticated techniques such as Generalised Method of Moments may prove to be fruitful. There is also the need to further disentangle human capital from intangible capital measures. Another area for further research is the potential for spillovers from intangibles within regions.

Notwithstanding these caveats, our findings do offer a number of policy relevant messages:

- Intangible assets are positively associated with productivity and productivity growth and, with the exception of R&D capital, this is not a phenomenon that appears to be sectorally concentrated.
- The occupational approach to intangible assets is a useful way of exploring its importance because it offers information on which occupations are increasingly important and growth enhancing.
- Further work linking the skills to occupations will assist in identifying priority skills for future growth.

# Annex: Additional Tables

### Table A1: List of occupational groups by intangible asset type:

| SOC code | Description | % of occ group 2006 |
|---|---|---|
| **R&D Workers** | | |
| 1137 | Research and development managers | 3.8 |
| 2111 | Chemists | 1.2 |
| 2112 | Biological scientists and biochemists | 5.4 |
| 2113 | Physicists, geologists and meteorologists | 1.0 |
| 2121 | Civil engineers | 4.2 |
| 2122 | Mechanical engineers | 4.6 |
| 2123 | Electrical engineers | 3.4 |
| 2124 | Electronics engineers | 2.6 |
| 2125 | Chemical engineers | 0.7 |
| 2126 | Design and development engineers | 4.7 |
| 2127 | Production and process engineers | 2.4 |
| 2128 | Planning and quality control engineers | 2.1 |
| 2129 | Engineering professionals n.e.c. | 5.2 |
| 2211 | Medical practitioners | 14.2 |
| 2213 | Pharmacists/pharmacologists | 2.7 |
| 2214 | Ophthalmic opticians | 0.8 |
| 2215 | Dental practitioners | 2.0 |
| 2216 | Veterinarians | 1.1 |
| 2321 | Scientific researchers | 1.2 |
| 2431 | Architects | 3.7 |
| 2432 | Town planners | 1.5 |
| 2433 | Quantity surveyors | 2.7 |
| 2434 | Chartered surveyors (not quantity surveyors) | 4.1 |
| 3111 | Laboratory technicians | 4.6 |
| 3112 | Electrical/electronics technicians | 2.0 |
| 3113 | Engineering technicians | 4.7 |
| 3114 | Building and civil engineering technicians | 1.7 |
| 3115 | Quality assurance technicians | 1.9 |
| 3119 | Science and engineering technicians n.e.c. | 2.8 |
| 3121 | Architectural technologists and town planning technicians | 2.0 |
| 3122 | Draughtspersons | 2.9 |
| 3551 | Conservation and environmental protection officers | 1.6 |
| 3552 | Countryside and park rangers | 0.5 |
| | | 100.0 |
| **IT Workers** | | |
| 1136 | Information and communication technology managers | 30.8 |
| 2131 | IT strategy and planning professionals | 16.0 |

| | | |
|---|---|---|
| 2132 | Software professionals | 33.7 |
| 3131 | IT operations technicians | 12.7 |
| 3132 | IT user support technicians | 6.9 |
| | | 100.0 |
| **Organisational Workers (management & marketing)** | | |
| 2421 | Chartered and certified accountants | 8.9 |
| 2422 | Management accountants | 4.1 |
| 2423 | Management consultants, actuaries, economists and statisticians | 7.2 |
| 2411 | Solicitors and lawyers, judges and coroners | 8.3 |
| 2419 | Legal professionals n.e.c. | 1.3 |
| 1131 | Financial managers and chartered secretaries | 10.5 |
| 2322 | Social science researchers | 1.4 |
| 3520 | Legal associate professionals | 2.3 |
| 1132 | Marketing and sales managers | 28.9 |
| 1134 | Advertising and public relations managers | 2.9 |
| 3421 | Graphic designers | 5.8 |
| 3422 | Product, clothing and related designers | 3.2 |
| 3432 | Broadcasting associate professionals | 2.2 |
| 1112 | Directors and chief executives of major organisations | 2.4 |
| 1123 | Managers in mining and energy | 0.6 |
| 1173 | Senior officers in fire, ambulance, prison and related services | 0.9 |
| 1181 | Hospital and health service managers | 4.6 |
| 1184 | Social services managers | 2.8 |
| 3541 | Buyers and purchasing officers | 1.2 |
| 3413 | Actors, entertainers | 0.1 |
| 3414 | Dancers and choreographers | - |
| 3415 | Musicians | 0.1 |
| 5496 | Floral arrangers, florists | - |
| 7125 | Merchandisers and window dressers | 0.2 |
| | | 100.0 |
| **Organisational workers in larger firms (10+ employees)** | | |
| 1121 | Production, works and maintenance managers | 23.1 |
| 1122 | Managers in construction | 13.4 |
| 1151 | Financial institution managers | 1.5 |
| 1161 | Transport and distribution managers | 5.9 |
| 1162 | Storage and warehouse managers | 6.3 |
| 1163 | Retail and wholesale managers | 16.5 |
| 1182 | Pharmacy managers | 0.3 |
| 1183 | Healthcare practice managers | 1.3 |
| 1185 | Residential and day care managers | 3.7 |
| 1211 | Farm managers | 0.1 |

| | | |
|---|---|---|
| 1212 | Natural environment and conservation managers | 0.4 |
| 1219 | Managers in animal husbandry, forestry and fishing n.e.c. | 0.1 |
| 1221 | Hotel and accommodation managers | 2.2 |
| 1222 | Conference and exhibition managers | 0.8 |
| 1223 | Restaurant and catering managers | 6.7 |
| 1224 | Publicans and managers of licensed premises | 2.3 |
| 1225 | Leisure and sports managers | 2.5 |
| 1226 | Travel agency managers | 0.3 |
| 1231 | Property, housing and land managers | 4.2 |
| 1232 | Garage managers and proprietors | 1.5 |
| 1233 | Hairdressing and beauty salon managers and proprietors | 0.2 |
| 1235 | Recycling and refuse disposal managers | 0.5 |
| 1239 | Managers and proprietors in other services n.e.c. | 6.4 |
| | | 100.0 |

Notes: cells shaded (1121 to 1239) = occupations included only when the organisation has at least 10 employees; cells shaded (3541 to 7125) = occupations included for production and transport sectors only. % of occ group derived from the Labour Force Survey, wave 1, 2006. Data are population weighted.

**Table A2: City Regions unit of geography**

| | |
|---|---|
| 1 "Birm/Sand/Wolver" | 29 "Plymouth" |
| 2 "Bournemouth/Poole" | 30 "Portsmouth/Southampton" |
| 3 "Brighton/Hove" | 31 "Preston" |
| 4 "Bristol/S. Glouc" | 32 "Reading" |
| 5 "Cambridge" | 33 "Sheffield" |
| 6 "Carlisle" | 34 "Stoke on Trent" |
| 7 "Chester" | 35 "Swindon" |
| 8 "Colchester" | 36 "Telford and Wrekin" |
| 9 "Coventry" | 37 "Worcester" |
| 10 "Exeter" | 38 "York" |
| 11 "Greater London" | 39 "Cardiff" |
| 12 "Glouc/Chelt" | 40 "Swansea" |
| 13 "Ipswich" | 41 "Aberdeen" |
| 14 "Kingston upon Hull" | 42 "Dundee" |
| 15 "Leeds/Bradford" | 43 "Edinburgh" |
| 16 "Leicester" | 44 "Glasgow" |
| 17 "Lincoln" | *45 "Belfast"* |
| 18 "Liverpool" | *46 "Other NE"* |
| 19 "Luton" | *47 "Other NW"* |
| 20 "Manchester/Salford/Trafford" | *48 "Other Y&H"* |
| 21 "Middlesbrough/Stockton" | *49 "Other EM"* |
| 22 "Milton Keynes" | *50 "Other WM"* |
| 23 "Newcastle/Gates/Sund" | *51 "Other Eastern"* |
| 24 "Northampton" | *52 "Other SE"* |
| 25 "Norwich" | *53 "Other SW"* |
| 26 "Notts/Derby" | *54 "Other Wales"* |
| 27 "Oxford" | *55 "Other Scotland"* |
| 28"Peterborough" | *56 "Other NI"* |

Source: Robson et al, (2006)

**Table A3: A31 Industry list**

| Description | SIC2003 |
|---|---|
| AGRICULTURE, HUNTING, FORESTRY AND FISHING | AtB |
| MINING AND QUARRYING | C |
| FOOD , BEVERAGES AND TOBACCO | 15t16 |
| TEXTILES, TEXTILE , LEATHER AND FOOTWEAR | 17t19 |
| WOOD AND OF WOOD AND CORK | 20 |
| PULP, PAPER, PAPER , PRINTING AND PUBLISHING | 21t22 |
| CHEMICAL, RUBBER, PLASTICS AND FUEL | 23t25 |
| OTHER NON-METALLIC MINERAL | 26 |
| BASIC METALS AND FABRICATED METAL | 27t28 |
| MACHINERY, NEC | 29 |
| ELECTRICAL AND OPTICAL EQUIPMENT | 30t33 |
| TRANSPORT EQUIPMENT | 34t35 |
| MANUFACTURING NEC; RECYCLING | 36t37 |
| ELECTRICITY, GAS AND WATER SUPPLY | E |
| CONSTRUCTION | F |
| Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel | 50 |
| Wholesale trade and commission trade, except of motor vehicles and motorcycles | 51 |
| Retail trade, except of motor vehicles and motorcycles; repair of household goods | 52 |
| HOTELS AND RESTAURANTS | H |
| TRANSPORT AND STORAGE | 60t63 |
| POST AND TELECOMMUNICATIONS | 64 |
| FINANCIAL INTERMEDIATION | J |
| REAL ESTATE, RENTING AND BUSINESS ACTIVITIES | K |
| Real estate activities | 70 |
| Renting of m&eq and other business activities | 71t74 |
| PUBLIC ADMIN AND DEFENCE; COMPULSORY SOCIAL SECURITY | L |
| EDUCATION | M |
| HEALTH AND SOCIAL WORK | N |
| OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES | O |
| PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS | P |
| EXTRA-TERRITORIAL ORGANIZATIONS AND BODIES | Q |

**Table A4a: Sector results, dependent variable log gross output per hour, pooled OLS, labour quality omitted**

| | Mining and quarrying | Food, beverages and tobacco | Textiles, leather and footwear | Wood and cork | Pulp, paper, printing and publishing | Chemicals, rubber plastics and fuel | Other non-metallic mineral products | Basic and fabricated metals | Machinery NEC | Electrical and optical equipment |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment size band (250-2000) | -0.147 | -0.035*** | -0.022** | 0.029 | 0.066*** | -0.067*** | 0.037*** | -0.040*** | 0.020* | 0.062*** |
| | (0.108) | (0.010) | (0.009) | (0.035) | (0.013) | (0.009) | (0.014) | (0.010) | (0.010) | (0.010) |
| Employment size band (2000+) | -0.035 | 0.077** | -0.116*** | -0.140*** | 0.179*** | 0.051 | 0.129*** | 0.067 | 0.054 | 0.091 |
| | (0.099) | (0.030) | (0.037) | (0.024) | (0.032) | (0.037) | (0.023) | (0.067) | (0.035) | (0.056) |
| log R&D capital intensity (per hour) | 0.169** | -0.012** | 0.005 | 0.083*** | 0.061*** | 0.144*** | 0.043*** | 0.113*** | 0.093*** | 0.073*** |
| | (0.085) | (0.005) | (0.005) | (0.016) | (0.008) | (0.009) | (0.005) | (0.008) | (0.013) | (0.012) |
| log organisation capital intensity (per hour) | 0.224*** | 0.295*** | 0.373*** | 0.296*** | 0.360*** | 0.186*** | 0.268*** | 0.252*** | 0.253*** | 0.285*** |
| | (0.077) | (0.014) | (0.014) | (0.025) | (0.017) | (0.012) | (0.020) | (0.010) | (0.014) | (0.013) |
| log IT capital intensity (per hour) | 0.027 | 0.035*** | 0.025*** | 0.043*** | 0.044*** | 0.022*** | 0.010*** | 0.051*** | 0.011*** | -0.002 |
| | (0.020) | (0.003) | (0.003) | (0.008) | (0.009) | (0.003) | (0.004) | (0.002) | (0.004) | (0.005) |
| log tangible capital intensity (per hour) | 0.013 | 0.018*** | -0.005** | 0.013** | 0.008*** | 0.008*** | 0.013*** | 0.008*** | -0.004* | 0.007** |
| | (0.014) | (0.004) | (0.002) | (0.007) | (0.002) | (0.003) | (0.004) | (0.002) | (0.002) | (0.003) |
| log materials intensity (per hour) | 0.487*** | 0.587*** | 0.530*** | 0.480*** | 0.421*** | 0.546*** | 0.543*** | 0.452*** | 0.479*** | 0.499*** |
| | (0.037) | (0.010) | (0.010) | (0.019) | (0.011) | (0.010) | (0.018) | (0.008) | (0.011) | (0.009) |
| Constant | 1.359*** | 2.105*** | 1.458*** | 1.501*** | 1.313*** | 1.158*** | 0.970*** | 1.317*** | 0.710*** | 0.841*** |
| | (0.441) | (0.315) | (0.084) | (0.144) | (0.070) | (0.065) | (0.106) | (0.051) | (0.064) | (0.060) |
| Observations | 719 | 7084 | 5939 | 2287 | 9370 | 9198 | 3063 | 12862 | 7959 | 8640 |
| R-squared | 0.775 | 0.858 | 0.856 | 0.798 | 0.781 | 0.862 | 0.824 | 0.800 | 0.773 | 0.812 |

Note: Year dummies included. Robust standard errors in parentheses; Asterisks' indicate statistical significance at the ***1%, **5%, *10% levels.

**Table A4b: Sector results continued, labour quality omitted**

| | Transport equipment | Manufacturing NEC | Sale & repair of motor vehicles ; retail of fuel | Wholesale, except of motor vehicles and motorcycles | Retail trade; repair of household goods | Hotels and Restaurants | Transport and Storage | Post and Telecoms | Renting and other business activities | Other Community social services |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment size band (250-2000) | 0.043*** | -0.098*** | -0.054*** | 0.059*** | -0.036*** | -0.130*** | -0.095*** | -0.032 | -0.042*** | 0.160*** |
| | (0.012) | (0.011) | (0.008) | (0.008) | (0.005) | (0.009) | (0.010) | (0.028) | (0.006) | (0.015) |
| Employment size band (2000+) | 0.166*** | 0.006 | -0.040** | 0.123*** | 0.003 | -0.059*** | -0.025 | 0.101*** | 0.105*** | 0.247*** |
| | (0.035) | (0.068) | (0.016) | (0.019) | (0.006) | (0.015) | (0.020) | (0.038) | (0.018) | (0.035) |
| log R&D capital intensity (per hour) | 0.027*** | 0.024*** | 0.016*** | 0.002 | 0.045*** | 0.004* | 0.012*** | -0.006 | 0.080*** | -0.025*** |
| | (0.008) | (0.005) | (0.004) | (0.003) | (0.002) | (0.002) | (0.003) | (0.006) | (0.003) | (0.005) |
| log organisation capital intensity (per hour) | 0.221*** | 0.281*** | 0.112*** | 0.217*** | 0.180*** | 0.370*** | 0.306*** | 0.286*** | 0.314*** | 0.397*** |
| | (0.015) | (0.014) | (0.007) | (0.006) | (0.003) | (0.005) | (0.009) | (0.036) | (0.005) | (0.009) |
| log IT capital intensity (per hour) | 0.020*** | 0.034*** | 0.015*** | 0.008*** | 0.010*** | 0.072*** | 0.063*** | 0.055** | 0.091*** | 0.044*** |
| | (0.004) | (0.006) | (0.003) | (0.002) | (0.002) | (0.003) | (0.005) | (0.027) | (0.005) | (0.007) |
| log tangible capital intensity (per hour) | 0.022*** | 0.012*** | 0.001 | 0.003* | -0.001 | 0.009*** | 0.040*** | 0.024*** | 0.009*** | 0.019*** |
| | (0.005) | (0.004) | (0.002) | (0.002) | (0.001) | (0.001) | (0.006) | (0.008) | (0.002) | (0.004) |
| log materials intensity (per hour) | 0.517*** | 0.519*** | 0.710*** | 0.707*** | 0.636*** | 0.455*** | 0.516*** | 0.479*** | 0.319*** | 0.457*** |
| | (0.013) | (0.011) | (0.006) | (0.004) | (0.005) | (0.006) | (0.006) | (0.015) | (0.003) | (0.006) |
| Constant | 0.707*** | 1.210*** | 0.450*** | 0.830*** | 0.673*** | 1.543*** | 2.137*** | 1.129*** | 0.971*** | 1.532*** |
| | (0.098) | (0.100) | (0.041) | (0.027) | (0.021) | (0.036) | (0.111) | (0.101) | (0.046) | (0.082) |
| Observations | 4314 | 5439 | 16549 | 37177 | 40886 | 21095 | 15219 | 1803 | 50003 | 20460 |
| R-Squared | 0.792 | 0.798 | 0.910 | 0.890 | 0.824 | 0.762 | 0.833 | 0.815 | 0.751 | 0.597 |

Note: Year dummies included. Robust standard errors in parentheses; Asterisks' indicate statistical significance at the ***1%, **5%, *10% levels.

**Table A5a: Sector results, dependent variable log gross output per hour, Random effects**

| | Mining and quarrying | Food, beverages and tobacco | Textiles, leather and footwear | Wood and cork | Pulp, paper, printing and publishing | Chemicals, rubber plastics and fuel | Other non-metallic mineral products | Basic and fabricated metals | Machinery NEC | Electrical and optical equipment |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment size band (250-2000) | -0.014 | 0.046*** | 0.010 | 0.019 | 0.083*** | -0.010 | 0.086*** | -0.005 | 0.023 | 0.015 |
| | (0.074) | (0.012) | (0.013) | (0.043) | (0.025) | (0.012) | (0.022) | (0.013) | (0.015) | (0.013) |
| Employment size band (2000+) | 0.048 | 0.067** | -0.114** | -0.161*** | 0.129*** | 0.091** | 0.164*** | 0.198* | 0.055 | 0.087* |
| | (0.091) | (0.029) | (0.046) | (0.023) | (0.047) | (0.040) | (0.025) | (0.106) | (0.056) | (0.048) |
| log R&D capital intensity (per hour) | 0.113 | -0.011** | 0.005 | 0.035*** | 0.083*** | 0.149*** | 0.046*** | 0.128*** | 0.124*** | 0.146*** |
| | (0.073) | (0.005) | (0.005) | (0.012) | (0.011) | (0.013) | (0.007) | (0.009) | (0.018) | (0.015) |
| log organisation capital intensity (per hour) | 0.393*** | 0.394*** | 0.415*** | 0.424*** | 0.418*** | 0.239*** | 0.334*** | 0.282*** | 0.291*** | 0.245*** |
| | (0.078) | (0.019) | (0.017) | (0.030) | (0.020) | (0.017) | (0.024) | (0.011) | (0.018) | (0.015) |
| log IT capital intensity (per hour) | 0.040* | 0.025*** | 0.030*** | 0.041*** | 0.039*** | 0.020*** | 0.015*** | 0.050*** | 0.015** | 0.008 |
| | (0.021) | (0.003) | (0.004) | (0.008) | (0.009) | (0.004) | (0.005) | (0.003) | (0.006) | (0.006) |
| log tangible capital intensity (per hour) | 0.009 | 0.015*** | 0.001 | 0.013* | 0.009*** | 0.007*** | 0.006* | 0.009*** | 0.002 | 0.007** |
| | (0.017) | (0.005) | (0.002) | (0.007) | (0.003) | (0.002) | (0.003) | (0.002) | (0.003) | (0.003) |
| log materials intensity (per hour) | 0.391*** | 0.479*** | 0.471*** | 0.377*** | 0.338*** | 0.456*** | 0.461*** | 0.388*** | 0.407*** | 0.451*** |
| | (0.050) | (0.017) | (0.014) | (0.025) | (0.014) | (0.015) | (0.026) | (0.009) | (0.014) | (0.012) |
| Constant | 1.692*** | 0.000 | 0.000 | 1.501*** | 0.000 | 1.162*** | 0.000 | 0.000 | 0.975*** | 1.089*** |
| | (0.437) | (0.000) | (0.000) | (0.148) | (0.000) | (0.066) | (0.000) | (0.000) | (0.078) | (0.072) |
| Observations | 719 | 7084 | 5939 | 2287 | 9370 | 9198 | 3063 | 12862 | 7959 | 8640 |
| Number of firms | 276 | 2936 | 2825 | 1392 | 4854 | 4001 | 1346 | 6830 | 3922 | 4089 |
| sigma_u | 0.376 | 0.347 | 0.285 | 0.298 | 0.305 | 0.257 | 0.315 | 0.282 | 0.263 | 0.281 |
| sigma_e | 0.204 | 0.196 | 0.175 | 0.134 | 0.185 | 0.158 | 0.159 | 0.170 | 0.185 | 0.185 |
| Rho | 0.772 | 0.759 | 0.726 | 0.831 | 0.730 | 0.726 | 0.797 | 0.734 | 0.669 | 0.697 |

Note: Year dummies included. Robust standard errors in parentheses; Asteriscs indicate statistical significance at the ***1%, **5%, *10% levels.

**Table A5b: Sector results continued, dependent variable log gross output per hour, Random effects**

| | Transport equipment | Manufacturing NEC | Sale & repair of motor vehicles ; retail of fuel | Wholesale, except of motor vehicles and motorcycles | Retail trade; repair of household goods | Hotels and Restaurants | Transport and Storage | Post and Telecoms | Renting and other business activities | Other Community social services |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment size band (250-2000) | 0.067*** | -0.047** | -0.027** | 0.030*** | -0.016* | -0.081*** | -0.050*** | 0.028 | -0.036*** | 0.069*** |
| | (0.021) | (0.020) | (0.011) | (0.011) | (0.010) | (0.013) | (0.014) | (0.038) | (0.009) | (0.018) |
| Employment size band (2000+) | 0.147** | 0.025 | -0.015 | 0.073*** | 0.001 | -0.040* | -0.016 | 0.018 | 0.020 | 0.092** |
| | (0.073) | (0.055) | (0.045) | (0.022) | (0.011) | (0.024) | (0.029) | (0.068) | (0.022) | (0.042) |
| log R&D capital intensity (per hour) | 0.041*** | 0.030*** | 0.005 | 0.005 | 0.048*** | 0.010*** | 0.001 | -0.022** | 0.090*** | -0.008 |
| | (0.009) | (0.005) | (0.005) | (0.004) | (0.002) | (0.002) | (0.004) | (0.009) | (0.003) | (0.007) |
| log organisation capital intensity (per hour) | 0.268*** | 0.333*** | 0.158*** | 0.243*** | 0.190*** | 0.384*** | 0.359*** | 0.326*** | 0.361*** | 0.449*** |
| | (0.021) | (0.017) | (0.009) | (0.008) | (0.004) | (0.005) | (0.010) | (0.033) | (0.006) | (0.011) |
| log IT capital intensity (per hour) | 0.019*** | 0.042*** | 0.016*** | 0.014*** | 0.014*** | 0.071*** | 0.068*** | 0.110*** | 0.092*** | 0.063*** |
| | (0.006) | (0.006) | (0.003) | (0.003) | (0.003) | (0.003) | (0.005) | (0.026) | (0.005) | (0.008) |
| log tangible capital intensity (per hour) | 0.019*** | 0.011*** | -0.000 | 0.002 | -0.000 | 0.008*** | 0.031*** | 0.017*** | 0.012*** | 0.020*** |
| | (0.006) | (0.003) | (0.003) | (0.002) | (0.001) | (0.001) | (0.005) | (0.006) | (0.001) | (0.004) |
| log materials intensity (per hour) | 0.447*** | 0.457*** | 0.684*** | 0.669*** | 0.617*** | 0.416*** | 0.449*** | 0.417*** | 0.258*** | 0.353*** |
| | (0.018) | (0.015) | (0.007) | (0.006) | (0.005) | (0.007) | (0.008) | (0.016) | (0.003) | (0.007) |
| Constant | 0.000 | 1.396*** | 0.000 | 0.954*** | 0.000 | 0.000 | 2.098*** | 1.288*** | 1.124*** | 0.000 |
| | (0.000) | (0.103) | (0.000) | (0.032) | (0.000) | (0.000) | (0.102) | (0.111) | (0.045) | (0.000) |
| | | | | | | | | | | |
| Observations | 4314 | 5439 | 16549 | 37177 | 40886 | 21095 | 15219 | 1803 | 50003 | 20460 |
| Number of firms | 1738 | 2946 | 10812 | 23368 | 31835 | 15582 | 9035 | 1170 | 34192 | 15090 |
| sigma_u | 0.297 | 0.290 | 0.293 | 0.314 | 0.303 | 0.292 | 0.416 | 0.465 | 0.492 | 0.758 |
| sigma_e | 0.200 | 0.185 | 0.154 | 0.179 | 0.156 | 0.177 | 0.217 | 0.194 | 0.224 | 0.265 |
| Rho | 0.687 | 0.710 | 0.783 | 0.756 | 0.791 | 0.732 | 0.787 | 0.852 | 0.829 | 0.891 |

Note: Year dummies included. Robust standard errors in parentheses; Asteriscs indicate statistical significance at the ***1%, **5%, *10% levels.

**Table A6a: Sector results, dependent variable log gross output per hour, fixed effects**

| | Mining and quarrying | Food, beverages and tobacco | Textiles, leather and footwear | Wood and cork | Pulp, paper, printing and publishing | Chemicals, rubber plastics and fuel | Other non-metallic mineral products | Basic and fabricated metals | Machinery NEC | Electrical and optical equipment |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment size band (250-2000) | 0.119 | 0.068*** | 0.033 | 0.100 | 0.124** | 0.047** | 0.118*** | 0.015 | 0.083*** | 0.005 |
| | (0.121) | (0.020) | (0.024) | (0.073) | (0.057) | (0.019) | (0.038) | (0.023) | (0.029) | (0.022) |
| Employment size band (2000+) | 0.000 | 0.024 | -0.166 | 0.000 | 0.147 | 0.142** | 0.000 | 0.320 | 0.183 | 0.076 |
| | (0.000) | (0.042) | (0.102) | (0.000) | (0.095) | (0.059) | (0.000) | (0.230) | (0.144) | (0.069) |
| log R&D capital intensity (per hour) | -0.072 | 0.005 | 0.025 | 0.015 | 0.043 | 0.172*** | 0.054*** | 0.191*** | 0.211*** | 0.209*** |
| | (0.157) | (0.009) | (0.016) | (0.021) | (0.047) | (0.026) | (0.018) | (0.021) | (0.035) | (0.027) |
| log organisation capital intensity (per hour) | 0.779*** | 0.447*** | 0.457*** | 0.604*** | 0.605*** | 0.300*** | 0.384*** | 0.298*** | 0.379*** | 0.215*** |
| | (0.168) | (0.030) | (0.033) | (0.068) | (0.058) | (0.031) | (0.042) | (0.024) | (0.039) | (0.032) |
| log IT capital intensity (per hour) | -0.023 | 0.007 | 0.003 | 0.042** | 0.038** | 0.013** | 0.011 | 0.026*** | 0.013 | 0.018 |
| | (0.042) | (0.005) | (0.008) | (0.017) | (0.017) | (0.006) | (0.008) | (0.007) | (0.018) | (0.012) |
| log tangible capital intensity (per hour) | -0.003 | 0.012 | 0.004 | 0.001 | 0.011 | 0.006* | 0.004 | 0.008** | 0.014* | 0.008 |
| | (0.025) | (0.008) | (0.003) | (0.013) | (0.008) | (0.004) | (0.004) | (0.004) | (0.008) | (0.005) |
| log materials intensity (per hour) | 0.331*** | 0.366*** | 0.384*** | 0.191*** | 0.196*** | 0.373*** | 0.379*** | 0.311*** | 0.278*** | 0.422*** |
| | (0.080) | (0.035) | (0.031) | (0.048) | (0.027) | (0.027) | (0.052) | (0.020) | (0.027) | (0.027) |
| Constant | 1.905*** | 1.204*** | 1.155*** | 1.571*** | 1.675*** | 1.272*** | 1.037*** | 1.312*** | 1.626*** | 1.278*** |
| | (0.655) | (0.163) | (0.196) | (0.298) | (0.169) | (0.106) | (0.182) | (0.121) | (0.171) | (0.145) |
| | | | | | | | | | | |
| Observations | 719 | 7084 | 5939 | 2287 | 9370 | 9198 | 3063 | 12862 | 7959 | 8640 |
| R-Squared | 0.696 | 0.587 | 0.642 | 0.637 | 0.476 | 0.637 | 0.608 | 0.601 | 0.557 | 0.654 |
| Number of firms | 276 | 2936 | 2825 | 1392 | 4854 | 4001 | 1346 | 6830 | 3922 | 4089 |

Note: Year dummies included. Robust standard errors in parentheses; Asteriscs indicate statistical significance at the ***1%, **5%, *10% levels.

**Table A6b: Sector results continued, dependent variable log gross output per hour, fixed effects**

| | Transport equipment | Manufact-uring NEC | Sale & repair of motor vehicles ; retail of fuel | Wholesale, except of motor vehicles and motorcycles | Retail trade; repair of household goods | Hotels and Restaurants | Transport and Storage | Post and Telecoms | Renting and other business activities | Other Community social services |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment size band (250-2000) | 0.111** | 0.023 | 0.046** | 0.033 | 0.015 | 0.007 | 0.009 | 0.079 | 0.016 | 0.071 |
| | (0.048) | (0.042) | (0.022) | (0.022) | (0.031) | (0.036) | (0.033) | (0.084) | (0.019) | (0.048) |
| Employment size band (2000+) | 0.105 | 0.132 | 0.091 | 0.068 | 0.089** | 0.115* | 0.021 | 0.034 | 0.105** | 0.129 |
| | (0.150) | (0.108) | (0.129) | (0.057) | (0.041) | (0.068) | (0.061) | (0.185) | (0.044) | (0.111) |
| log R&D capital intensity (per hour) | 0.151*** | 0.035** | -0.022* | 0.002 | 0.027** | -0.020** | 0.005 | -0.012 | 0.086*** | 0.007 |
| | (0.034) | (0.014) | (0.013) | (0.010) | (0.013) | (0.009) | (0.011) | (0.026) | (0.010) | (0.020) |
| log organisation capital intensity (per hour) | 0.269*** | 0.463*** | 0.286*** | 0.319*** | 0.292*** | 0.676*** | 0.447*** | 0.467*** | 0.558*** | 0.581*** |
| | (0.042) | (0.042) | (0.038) | (0.030) | (0.027) | (0.033) | (0.030) | (0.077) | (0.022) | (0.041) |
| log IT capital intensity (per hour) | 0.005 | 0.042*** | 0.013 | 0.046*** | 0.047*** | -0.016 | 0.056*** | 0.123*** | 0.061*** | 0.091*** |
| | (0.012) | (0.014) | (0.009) | (0.010) | (0.011) | (0.012) | (0.016) | (0.046) | (0.014) | (0.021) |
| log tangible capital intensity (per hour) | 0.016 | 0.006* | -0.001 | 0.000 | -0.001 | -0.001 | 0.025*** | 0.006 | 0.009*** | 0.016 |
| | (0.010) | (0.003) | (0.006) | (0.004) | (0.005) | (0.003) | (0.009) | (0.005) | (0.003) | (0.011) |
| log materials intensity (per hour) | 0.388*** | 0.327*** | 0.659*** | 0.598*** | 0.491*** | 0.275*** | 0.311*** | 0.291*** | 0.142*** | 0.203*** |
| | (0.040) | (0.037) | (0.039) | (0.033) | (0.035) | (0.025) | (0.024) | (0.050) | (0.008) | (0.023) |
| Constant | 1.036*** | 1.527*** | 1.086*** | 1.406*** | 1.090*** | 1.589*** | 1.704*** | 1.584*** | 1.289*** | 2.006*** |
| | (0.252) | (0.217) | (0.157) | (0.112) | (0.122) | (0.150) | (0.202) | (0.337) | (0.160) | (0.501) |
| | | | | | | | | | | |
| Observations | 4314 | 5439 | 16549 | 37177 | 40886 | 21095 | 15219 | 1803 | 50003 | 20460 |
| R-squared | 0.572 | 0.569 | 0.773 | 0.731 | 0.684 | 0.689 | 0.578 | 0.698 | 0.557 | 0.533 |
| Number of firms | 1738 | 2946 | 10812 | 23368 | 31835 | 15582 | 9035 | 1170 | 34192 | 15090 |

Note: Year dummies included. Robust standard errors in parentheses; Asteriscs indicate statistical significance at the ***1%, **5%, *10% levels

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