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WORKFORCE SKILLS AND INNOVATION: AN OVERVIEW OF MAJOR THEMES IN THE LITERATURE

By Phillip Toner

This paper provides an account of the main approaches, debates and evidence in the literature on the role of workforce skills in the innovation process in developed economies. It draws on multiple sources including the innovation studies discipline, neoclassical Human Capital theory, institutionalist labour market studies and the work organisation discipline. Extensive use is also made of official survey data to describe and quantify the diversity of skills and occupations involved in specific types of innovation activities.

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WORKFORCE SKILLS AND INNOVATION: AN OVERVIEW OF MAJOR THEMES IN THE LITERATURE

Phillip Toner*

Abstract

This paper provides an account of the main approaches, debates and evidence in the literature on the role of workforce skills in the innovation process in developed economies. It draws on multiple sources including the innovation studies discipline, neoclassical Human Capital theory, institutionalist labour market studies and the work organisation discipline. Extensive use is also made of official survey data to describe and quantify the diversity of skills and occupations involved in specific types of innovation activities.

The principal debates within the literature are outlined and evaluated. These debates centre on the definition of ‘skill’; the idea of generic ‘skills for innovation’; the contribution of skills supply in promoting innovation; the apparent paradox of simultaneous skill shortages and ‘over-qualification’ in the workforce; the notion of ‘high or low-skill equilibrium’; how industry and training systems balance the demands for workers to acquire firm-specific skills of immediate value in the market against more general skills and knowledge that may be relevant to a broader range of firms and technologies over a working life; the role of different work organisation systems in promoting and utilising workforce skills and whether technical change is fundamentally biased towards demanding higher level workforce skills.

The paper identifies a number of major findings in the literature. First, the predominant form of innovation in firms is incremental, and this points to the central role of the broader workforce in the generation, adaptation and diffusion of technical and organisational change. Second, achieving high academic standards within a country for the largest proportion of school students not only supports high participation in post school education and training but creates a workforce with greater potential to engage productively with innovation. Third, the extent to which a firm’s workforce actively engages in innovation is strongly determined by particular work organisation practices. Finally, there are large differences across advanced nations in workforce skill formation systems, especially for vocational skills. Such differences result in large disparities across nations in the share of their workforce with formal vocational qualifications, and in the level of these qualifications. The resulting differences in the quantity and quality of workforce skills are a major factor in determining the observed patterns of innovation and key aspects of economic performance.

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COMPÉTENCES DE LA MAIN D'OEUVRE ET INNOVATION : PANORAMA DES PRINCIPAUX THÈMES TRAITÉS DANS LA LITTÉRATURE

Phillip Toner*

Abstract

Ce rapport présente un tour d'horizon des grands courants de pensée, des débats et des éléments factuels que l'on trouve dans la littérature consacrée au rôle des compétences de la main d'œuvre dans le processus d'innovation dans les économies développées. Il s'appuie sur de multiples sources, notamment dans les domaines de l'étude de l'innovation, de la théorie néoclassique du capital humain, des études institutionnalistes du marché du travail, et de l'organisation du travail. Un large usage a été fait des données issues des enquêtes officielles, qui permettent de décrire et de quantifier l'éventail des compétences et des métiers impliqués dans les différents types d'activités d'innovation.

Les principaux débats développés dans la littérature sont décrits dans leurs grandes lignes et évalués. Ces débats sont centrés autour de : la définition de « compétence » ; l'idée de « compétences génériques pour l'innovation » ; l'influence de l'offre et de la demande de compétences dans la promotion de l'innovation ; la coexistence apparemment paradoxale de pénuries de compétences et d'une « surqualification » de la main d'œuvre ; la notion de « niveau bas ou élevé du point d'équilibre des compétences » ; l'arbitrage fait par les entreprises et les systèmes de formation entre la nécessité pour les travailleurs d'acquérir des compétences spécifiques à l'entreprise ou immédiatement monnayables sur le marché du travail et le besoin qu'ils ont de s'approprier des compétences et des connaissances plus génériques qui resteront pertinentes tout au long de leur vie active par-delà l'évolution des technologies ; le rôle des différents systèmes d'organisation du travail dans la valorisation et l'exploitation des compétences de la main d'œuvre et la question de savoir si le progrès technologique suppose nécessairement que la demande s'oriente vers une main d'œuvre ayant un niveau de compétence plus élevé.

Ce rapport met en évidence quelques enseignements majeurs qui ressortent de la littérature. Premièrement, la forme prédominante de l'innovation dans les entreprises est incrémentale, ce qui signifie que l'ensemble de la main d'œuvre joue un rôle dans la production, l'adaptation et la diffusion du changement technique et organisationnel. Deuxièmement, le fait que, dans un pays donné, une forte proportion de la population atteigne un niveau scolaire élevé signifie non seulement qu'il y a une plus forte participation dans l'enseignement et la formation post-secondaires, mais aussi que la main d'œuvre est potentiellement plus apte à prendre part de manière productive à l'innovation. Troisièmement, le rôle, actif ou non, joué par la main d'œuvre d'une entreprise dans la promotion de l'innovation est déterminé par les pratiques suivies en matière d'organisation du travail. Enfin, les systèmes de formation de la main d'œuvre des pays développés présentent un tableau contrasté, en particulier s'agissant de l'enseignement professionnel. Il en découle d'importantes disparités d'un pays à l'autre en ce qui concerne la part de la main d'œuvre qui dispose de qualifications validées, et le niveau de ces qualifications. Les différences qui en découlent en termes de quantité et de qualité des compétences de la main d'œuvre constituent un facteur déterminant pour l'innovation telle qu'on peut l'observer et certains aspects clés de la performance économique.

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1. WORKFORCE SKILLS AND INNOVATION

Introduction

The topic of skills, knowledge and innovation has generated a vast body of research over the last four decades across several discrete disciplines including innovation studies, sociology, economics, economic history, psychology and education. More recently it has also attracted increased interest from public policy makers. Accordingly, this report is not an exhaustive review of the existing literature; rather its purpose is to provide a concise critical overview of the major themes in the literature on the role of workforce skills in innovation in OECD countries. A particular focus is to provide an understanding of the diversity of approaches, methods and results in this literature. It also provides a concise account of the principal criticisms of the dominant approaches. This overview adopts an inclusive definition of ‘skills’ as it is taken to encompass the range from the abstract concept of ‘knowledge’ to concrete occupationally specific attributes and competencies. The purpose of the overview is purely descriptive; it does not advocate any particular approach.

A key finding of this study is that overall the evidence supports a strong causal inter-relation between the supply of higher levels of education, training and skills and increased demand for and supply of technical and organisational innovation. At the most fundamental level it has been shown that investment in capital equipment, innovation and human capital are broadly complementary and mutually reinforcing (Lloyd-Ellis and Roberts, 2002). That is to say, at an economy–wide level an increase in the capital-labour ratio and other innovation-related investments such as R&D and organisational re-structuring are associated with an increase in the supply of and demand for higher skills. A broad range of mechanisms has been identified to account for this cumulative causation within the sphere of production and consumption. These include, for example, the rapid growth in the ‘volume’ of productive knowledge requires ever higher capacity on the part of firms and individuals to identify, evaluate and adapt this knowledge. An increased rate of technical change introduces greater ‘uncertainty’ for firms, which, in turn, demands an increased capacity for adaptability and more widely distributed problem solving skills. It is also argued that higher workforce skills are compelled by an ever growing intensity of competition which has shifted the strategy of many firms in developed economies towards ‘diversified quality production’ (Streeck, 1989; Vickery and Wurzburg, 1996).

However, by employing a multi-disciplinary approach to the topic of skills and innovation it is clear that the research is also more contested, and its results more nuanced, than often presented in many research reports or public policy documents. These more critical studies do not deny the overall link between higher skills and innovation but suggest, firstly, the link is less robust than that widely claimed and secondly, there is no universal tendency for an increase in the demand for skills across all forms of innovation, industries and occupations. These critical studies suggest, for example, that innovation may on occasion lead to a reduction in skill content or ‘de-skilling’; that the causes of rising income inequality between low and highly educated workers over the last three decades in Anglo-Saxon countries may be due largely to factors other than ‘skill biased technical change’ and a surprisingly large proportion of educated workers are employed in jobs requiring minimal training. Moreover, some studies argue that certain labour market developments, notably, the rise of non-standard forms of employment, such as casualisation and self-employment, and some types of labour migration can have adverse effects on workforce capacity for innovation. These labour market developments have been argued to reduce the incentive of employers to invest in workforce training and for employees to participate in workplace training.

To date a primary focus of research on the topic of skills and innovation within the innovation studies discipline has been on Human Resources for Science and Technology (HRST), that is, scientists, engineers and technologists (OECD, 2002a). This reflected the traditional 'linear' view of innovation as being one essentially of scientific Research and subsequent Development of new products and processes. Secondly, the focus of these studies was largely on HRST for product and process innovation in the manufacturing industry. There are sound reasons why this should have been the case. Across developed economies manufacturing accounted for a disproportionate share of expenditure on innovative activity, in particular R&D. Moreover, the outputs of manufacturing activity, notably capital goods such as computers and telecommunications equipment, to take two obvious examples, were, and are, used as key inputs to innovation in all industries. However, as manufacturing currently accounts for less than 15% of GDP across most OECD countries attention has increasingly shifted to innovation and workforce skills in service industries. A key concern of these studies is to determine whether the innovation process, and consequent demand for workforce skills, differs significantly from that in manufacturing.

Whilst it is undoubtedly the case that leading-edge scientific and engineering endeavours are a crucial stimulus to productivity and economic growth, over several decades the innovation studies literature has revealed that the broader non-HRST workforce and the non-science and engineering part of the HRST workforce also play an essential role in the innovation process.[1] Indeed, the internationally accepted definition of innovation, for the purpose of data collection and framing of public policy, encompasses a very broad range of activities, such as marketing and organisational improvement, which are typically the responsibility of persons trained in social sciences. Many studies have demonstrated the important role of the non-S&T workforce in developing and diffusing technical and organisational innovations. A key concept employed in these studies is the notion of 'incremental' innovation or gradual improvements in goods, services and organisational structures which improve the performance or expand the range of applications for existing technologies. The accumulation of these gradual improvements over time and across an entire economy accounts for much of the productivity growth and dynamism in capitalist societies. Incremental innovation occurs both in the direct production process and in final consumption through means such as workers and consumers adapting goods and services to better meet their particular needs and feedback provided by these groups to equipment and service producers (von Hippel, 2005). In turn, the capacity to engage in such innovation has been shown to depend critically on the technological 'absorptive capacity' of the workforce, broadly conceived of as the ability to adopt, adapt and diffuse new or improved products, production processes and organisational innovations. In turn it is generally argued that the increased rate of innovation across economies requires the workforce to possess both technical competence and what are termed 'generic skills' - problem solving, creativity, team work and communication skills. It has been found that the capacity of the non-HRST workforce to contribute to

1 Human Resources in Science and Technology is defined by the *Canberra Manual* (OECD 1995) as persons who:

- Hold education qualifications equivalent to the International Standard Classification of Education (ISCED 1998) at level 7 (post graduate-Master degrees or Doctoral degrees); level 6 (Bachelor or first university degree) and level 5 (technician level such as Diploma or Advanced Diploma).
- Are in seven broad S&T fields of study-Natural Sciences, Engineering and Technology, Medical Sciences, Agricultural Sciences, Social Sciences, Humanities and other fields and/or;
- Are working in an S&T occupation. Recommendations in the *Canberra Manual* identify certain occupational groups requiring skills that correspond to certain occupations within the International Standard Classification of Occupation (ISCO 1988) as HRST whether the person has a formal qualification or not. These occupations are Major Group 1 – Legislators, Senior Officials and Managers; Major Group 2 – Professionals and Major Group 3 – Technicians and Associate Professionals.

innovation at the firm level is a function of a range of factors such as high rates of participation in sound primary and secondary education; the availability of quality post-school vocational training; institutional structures which provide incentives for workers to invest in such training and work organisation at the firm level which encourages the full participation of workers in continuous product and process improvement.

1.1 Structure of the report

Chapter 2 begins with an outline of the reasons for growing policy and academic interest in the topic of skills and innovation and a summary of the reasons advanced for the increased demand for higher workforce skills. This chapter also briefly addresses the definition of skill and innovation. The chapter draws on official surveys of innovation in business to describe the great variety of activities encompassed by innovation and the corresponding range of skills required for their implementation. It also demonstrates the great diversity in innovation activities and skills across industries. Given the increased recognition of the importance of both incremental innovation and the key role of the wider workforce in its generation the chapter provides a summary of the main arguments on this topic in the literature and supporting data. A brief account is also provided of innovation and skills in service industries and across the product cycle.

As noted above, the subject of skills and innovation has been analysed through a variety of disciplines, each with their own methods and assumptions. Chapter 3 briefly summarises what are arguably the three most important approaches to the subject. The first is associated primarily with neoclassical economics, which highlights the importance of investment in human capital in the long-run growth of per capita income. A major theme over recent decades has been the application of the concept of ‘skills biased technical change’ to account for key structural changes in developed economies such as the much faster rate of growth of demand for labour services of university educated persons compared to total labour demand growth and the implied rise in income inequality. The second approach demonstrates how variations in national skill formation systems across developed economies generate large differences in quality and quantity of skills at a vocational and higher education level, which in turn, directly affects the capacity of firms and industries to implement innovation. The third approach argues that the rapid spread of organisational innovation, notably of ‘high performance work systems’, has increased the level and breadth of skills demanded of the workforce. A summary of critical perspectives on these approaches to skills and innovation is the subject of Chapter 4. Chapter 5 provides a summary and assessment of these conflicting perspectives and identifies some implications for public policy.

2. DEFINING SKILLS AND INNOVATION

This chapter briefly describes the various disciplinary approaches within the social sciences to the subject of skills and innovation and reasons for the growing academic and policy concern with the subject. It also examines the contentious issue of defining workforce skills and analyses the concept of innovation, focussing in particular on how the various forms of innovation, such as the distinction between incremental and radical innovation, affect the supply of and demand for different skills, knowledge and occupations.

2.1 Social sciences, innovation and skills

Within the field of innovation studies "current models of innovation and innovation diffusion accept the notion that all levels of skills are important, and that a sound basic education is the foundation upon which all adaptive innovation-related skills are based" (Pro Inno Europe, 2007: 35). Despite this recognition of the importance of workforce skills it is also the case that there "is little systematic knowledge about the ways in which the organization of education and training influences the development, diffusion and use of innovations" (Edquist 2005: 185). Within the innovation studies literature skills are typically dealt with in an abstract way, and especially for the non-HRST workforce, have rarely been the subject of detailed case studies, such as the role of particular occupations in the innovation process in particular settings.[2]

This contrasts with other fields of study in the humanities and social sciences. A persuasive case can be made that the topic of skills and their relation to the capacity for innovation, broadly conceived as technological and organisational change, has been a central concern of the social sciences since the early Industrial Revolution. For example, a central insight in the classical political economy of Adam Smith (1776) was that growth in the size of the market facilitates increased specialisation of both labour tasks (i.e., skill requirements) in production *and* capital equipment used by this labour. A century later Marx (1867) described the role of 'machinery and large scale industry', characterised by rapid increases in the capital-labour ratio, application of science to the capital goods sector and intensified division of labour in production. A central concern of post-war neoclassical economics has been the effect of technological change on the growth of per capita income and the contribution of human capital to such growth. (This topic is dealt with in more detail in Chapter 3).

Economic historians have demonstrated the role of particular occupations in innovation, such as the critical role of craftspeople in the genesis of the Industrial Revolution through their incremental improvements to machine tools, metallurgy, armaments, printing machines and steam engines (Landes, 1972). For example, an eighteenth century English wood worker was responsible for developing a marine chronometer sufficiently accurate to enable the precise calculation of longitude, which in turn, unpinned subsequent growth of international trade and colonial empires (Sobel, 1995).

In the field of comparative vocational training systems detailed empirical case studies have demonstrated the effect of different national systems of training and accreditation on the acquisition of

2 "There is surprisingly little literature within the 'innovation studies' tradition with an explicit focus on skills and skills formation, but the importance of skills and skill formation is implicit throughout the literature" (Tether *et al*, 2005: 73). A more recent study prepared for the European Union also revealed major gaps in the innovation literature on the links between skills and innovation. It concluded with a call for more research on such fundamental issues as the characteristics of skills required for incremental as opposed to radical innovation and the types of competences required across different innovation processes - product, process, organisational and marketing (Pro Inno Europe, 2007: 48-49).

skills and their impact on the capacity of production level workers, for example, to engage in innovation (Prais, 1995) (This topic is dealt with in more detail in Chapter 3).

The organisational studies literature also has a long tradition of interest in the interaction between work organisation, skills and technology. Work organisation involves issues such as authority and hierarchy within workplaces, autonomy and responsibility of labour and the allocation of skills and tasks across occupations. It highlights the social construction of skill: such as the bargaining and often bitter conflict between capital and labour that can occur at a workplace and industry level over the development and scope of skills embodied in particular occupations (Braverman, 1974). (This topic is dealt with in more detail in Chapter 3).

Ethnographic sociological studies based on the long term immersion of researchers in particular settings have centred on the examination of occupational and professional identity, status, power and different 'ways of knowing' such as the distinction between 'practical' and 'theoretical' knowledge (Barley and Bechky, 1994; Amin and Roberts, 2008).

Whilst a minimum level of workforce skills has been recognised in the innovation studies literature as a necessary condition for continuous product and process improvement, the specific types and qualities of such skills embedded in specific occupations and industries have not been a central concern of this literature. A broad variety of disciplines, each providing its own insights and methodology, must therefore be drawn upon to investigate the linkages between workforce skills and innovation. Taken together these various disciplines reveal a complex outcome of 'upskilling, deskilling, polarisation, or mixed changes' depending on the theoretical approach, data collection methods, and time period included in the analysis (Kim, 2002: 89).

2.2 Defining skills

2.2.1 Conventional approach

The general concept of skills refers to productive assets of the workforce that are acquired through learning activities. The literature, however, does not concur on a robust and accepted definition and classification of skills beyond this general characterisation. The following remarks are representative of the conclusion of many analytical studies of the concept of skill:

> *"The notion of "skill" has been one of the most elusive and hardest to-define concepts in labor economics" (Lafer, 2002: 75); [Despite its] central importance in discussions of labour market change…an appropriate and robust definition of skill has proven elusive. It seems that skill is a more complex and abstract concept or idea than current approaches have been able to capture" (Esposto, 2008: 100-01).*

In the now vast literature on the impact of technological change on skills a number of indirect indicators of skill level and change in skill level have been employed. Reflecting the elusive and subjective character of 'skill' these indicators are typically not the subject of detailed justification and investigation to determine their validity and reliability. They are usually adopted by the researchers as a pragmatic solution to the problem of defining skill or derived by assumption from the theoretical orientation of the researcher. The most important indicators to be found in the literature are:

- Employment distribution by level of occupation (Reich, 1990; Cully, 1999).

- Employment distribution by educational attainment (Colecchia and Papaconstantinou, 1996).

- Wage differentials by educational attainment or occupation (Goldin and Katz, 2007).

- Measuring change in the job tasks and attributes required to perform a job (Howell & Wolff, 1991; Esposto, 2008).

- Surveys of employers or employees to determine skill levels required to perform jobs (Felstead, Gallie and Green, 2002).

The overall conclusion of most studies over the last three to four decades, with some important exceptions, is that "[r]egardless of the measurement of skills...demand for high-skilled labour has risen since the 1970s. This trend is observed in both the manufacturing… and the service sector…as well as in the aggregate economy. The higher the skill level of jobs or occupations, the greater the skill upgrading is likely to be" (Kim, 2002: 91).

In many studies skills and skill levels are defined as some combination of education, training and experience (Machin and Van Reenan, 1998; Tether *et al*, 2005; Pro Inno Europe, 2007). This approach is taken by many national statistical agencies in the classification and definition of occupations for the collection of labour market data. These occupational classifications also, on occasion, include a cardinal ranking of occupations from most to least skilled based, for example, on the period of training required for entry into the occupation and/or years of experience to achieve competency in the occupation (Australian Bureau of Statistics, 2006a). Some agencies such as the US Department of Labor, in addition to using education, training and experience, have devised detailed taxonomies of skills comprising hundreds of different elements such as 'social perceptiveness', 'problem identification', 'equipment selection', 'identification of key causes' or 'management of financial resources'. These are used to define the scope of occupations and provide an ordinal ranking of these skills in terms of their importance for each occupation and across occupations (Esposto, 2008).

These classification systems are, however, not a solution to the problem of defining skill, to the ordinal or cardinal ranking of skill levels, or for assessing the role of changing technologies on skills.[3]

2.2.2 Inter-country differences in the meaning of skill

Other studies have highlighted important inter-country differences in the meaning, scope and delivery of skill, which, in turn, have implications for the capacity of the workforce to engage in innovation. For vocational or intermediate occupations it has been argued that there are important differences between the Anglo-Saxon conception of vocational skills and that in continental Europe, especially Germany, the Netherlands and France.

The main characteristics of the Anglo-Saxon concept of vocational skills are that:

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3 This may perhaps best be explained by way of example. In the past physicians of internal medicine relied largely on direct sensory information to identify and interpret often subtle symptoms. They used visual inspection, touch and pressure, even smell, or the interpretation of sound using relatively simple instruments such as the stethoscope. Over the last fifty years information and diagnosis is increasingly dependent on, and mediated through, test results from pathology labs or imaging techniques. There has surely been a change in methods of diagnosis, but which approach, reliance on direct sensory information or interpretation of test results, is the more skilled? The issue is even more complicated if other criteria are included in the assessment of change in the skill level of physicians over time, such as comparative success rates in identifying and curing disease. Does a higher cure rate of modern physicians compared to say fifty years ago mean that the latter are more skilled? What methods can be used to apportion improvements in success rates to change in skills of the physician or the development of new diagnostic instruments? Clearly, change in both skills and technology are mutually interdependent.

- It is understood as the attribute or property of an individual.
- It is associated with the performance of discrete tasks.
- It is associated with physical or manual dexterity and is not necessarily associated with a particular knowledge base.
- It is not directly related to the possession of a qualification, as they are not required for entry into many vocational occupations and nor are wage levels tied to the possession of qualifications (Clarke and Winch, 2006: 261).

This conception of skill is embedded for example in the UK National Vocational Qualification (NVQ) system which describes skills in terms of a discrete set of manual tasks or 'competencies' that are assessed through the performance of practical demonstrations. Because of the practical nature of the competencies and their assessment it is possible to acquire an NVQ without having undergone any formal training.

In contrast German *berufsbildung* (vocational education) is based on a different conception of skill:

- Recognising that production is an inherently social activity in which a student is taught how their activities fit in with and shape the performance of other occupations engaged in a production process.
- General education is included in the curriculum through subjects such as mathematics, foreign languages and civic education.
- The focus is on 'the ability to apply theoretical knowledge in a practical context', where theoretical knowledge encompasses not just technical subjects but mathematics, work planning, autonomous working, problem solving and critical thinking.
- Wages and increments in wages are linked to the attainment of qualifications (Clarke and Winch, 2006: 265).[4]

These differences in the conception of skill have long-run historical, philosophical and political origins dating at least to the formation of modern European nation states (Clarke and Winch, 2007). Pursuing this topic is beyond the scope of the present paper.

Wide differences in the conception of skill and content and delivery of vocational education give rise to large variations in the performance of vocationally trained workers across countries. In the United Kingdom VET workers are less able to deal with technological change and more complex problem solving "as people are required to perform to narrowly prescribed competencies, they do not have the knowledge, skills or indeed, the motivation to perform tasks or deal with situations beyond the prescribed outcomes" (Brockmann, Clarke and Winch, 2008: 553). (Section 3.3 provides a brief analysis of the institutional foundations of different national skill formation systems and their implications for innovation).

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4 The term 'dual system' is often used to describe German vocational education, but the nature of the 'duality' is rarely explained. Some aspects of the duality include- training occurs both in the workplace and off the job in technical colleges; the classroom training covers both technical training and broader educational subjects such as mathematics and civics; and the regulation and delivery of training is jointly managed by industry (including unions) and government.

This lack of equivalence of vocational qualifications, worker knowledge and ability across developed countries makes problematic moves, for example within the European Union, towards the mutual recognition of qualifications and encouragement of internal migration (Clarke and Winch, 2006: 267).

2.2.3 Changes in education, qualifications and occupations over time

Even within nations there are difficulties with the use of education or qualifications as a proxy for skill or human capital when looking at trends over some decades as such comparisons implicitly assume that quality is invariant over time.[5] If it is accepted that the stock of knowledge increases over time, and that it is incorporated in education or qualifications, it could be argued that more recent qualifications are more 'productive' than those obtained by previous generations. From a contrary viewpoint, it has been argued that a combination of the growth of mass higher education and reduced real government funding per student over recent decades across many advanced economies has resulted in higher staff-student ratios and "caused a degree of damage to the quality of university experience" (Deer, 2004: 205). A consequent increased reliance by universities on full-fee paying overseas and domestic students is argued to create incentives to lower standards to maintain income. Finally, some university degrees, outside the traditional professions, are increasingly 'vocational' in that they are tied to the needs of a narrow range of jobs, and it is claimed, do not provide a rounded general education whose purpose is to foster critical thinking (Deer, 2004: 205-206).

The use of occupational data to discern long-run trends in workforce skills has also been challenged. Jobs which previously required low educational attainment for entry are now being filled by people who have completed high school or even possess degrees. An increase in the relative supply of higher skills, in turn, alters the job content to increase the complexity of tasks and knowledge required of these occupations. (This is examined in more detail in section 4.1.5.)

2.2.4 The ever expanding scope of 'skills'

Not only is there substantial variation in the conception of skill across countries, there is also a recent tendency for researchers and policy makers, especially in Anglophone countries, to expand the range of tasks, knowledge and abilities that are deemed to be required to deal with new technologies and pace of innovation.

It is commonly argued that in addition to obtaining specific technical skills workers in different occupations are increasingly required to develop a broad range of what are variously termed 'generic', 'transferable' or 'employability' skills (HM Treasury, 2004; Sheldon and Thornthwaite, 2005; Tether *et al*, 2005; Taylor, 2006; Martin and Healy, 2008). The scope of these skills typically includes communication (verbal and written), numeracy, IT, team work, problem solving and learning to learn. These required attributes are also on occasion expanded to include leadership, motivation, discipline, self-confidence, self awareness, networking, entrepreneurship and capacity to embrace change. These skills are regarded as generic or transferable since they are "seen as having a broad application across a wide range of employment contexts and as transcending individual subjects" and are argued to be the basis for a "flexible" and "multiskilled" workforce (Keep and Payne, 2004: 57).

5 This problem is exacerbated in comparing education and qualifications across countries. 'Using average years of schooling as an education measure implicitly assumes that a year of schooling delivers the same increase in knowledge and skills regardless of the education system. For example, a year of schooling in Papua New Guinea is assumed to create the same increase in productive human capital as a year of schooling in Japan. Additionally, this measure assumes that formal schooling is the primary (sole) source of education and, again, that variations in the quality of nonschool factors have a negligible effect on education outcomes. This neglect of cross-country differences in the quality of education is probably the major drawback of such a quantitative measure of schooling' (Hanushek and Woessmann 2007: 21).

Rising demand for generic skills is argued to be a response to the application across most industries of ICT technologies requiring common or standardised skills. Widespread adoption of more efficient work organisation methods, such as lean production across both manufacturing and service industries, is also argued to demand the workforce acquire a broader range of skills.

While not denying the importance of competence in undertaking tasks such as communication, numeracy, ICT use, problem solving and continuous learning, nor their important role in innovation, it has been suggested that the concept of generic skills has inflated the scope of desirable worker attributes to the point where “the concept of skill becomes essentially meaningless” (Keep and Payne, 2004: 57). One effect of the widespread adoption of such a broad and, some suggest, amorphous concept as generic skills is that it presents potentially insurmountable difficulties for educational institutions charged with teaching these skills to a workforce. This is because there is little common agreement as to their scope and relative importance. In addition, many generic skills lack an objective means of determining degrees of competence for those receiving instruction. Related to this last point, it has been suggested that some ‘generic skills’ are an abstraction that have little direct applicability to particular conditions in particular workplaces. Proponents of the idea of generic skills, such as problem solving, regard them as being ‘context/domain independent’. On the contrary, it has been argued that “the ability to solve any given problem, above and beyond the most simple, relies on expertise and specialist bodies of knowledge” (Keep and Payne, 2004: 58). Finally, the widespread adoption in policy circles and by industry of the concept of generic skills may have the unintended adverse consequence of undermining workforce innovation capacity. The abstract and non-occupationally specific nature of generic skills implies that they can be readily acquired through formal education courses outside the workplace. Indeed, there are incentives for employers to shift the cost burden of such training onto government by having generic skills delivered in public education and training institutions. Such training could be integrated into existing educational and training courses or conducted separately. These developments have been opposed on several grounds. Skills such as problem solving and team work are actually acquired in the course of developing occupationally and firm-specific skills, and accordingly “the primary location for the creation and development of higher order work skills remains the workplace” (Keep and Payne, 2004: 68). Moreover, the incorporation of separate instruction in generic skills into existing educational and training courses for the workforce, such as degrees or trade training, runs the risk of displacing valuable occupationally or task specific technical content.

2.3 Defining innovation

The purpose of this section is firstly to provide a concise account of the concept of innovation, highlighting the great variety of economic, technical and organisational activities it encompasses. Secondly, it briefly describes the key ‘stylised facts’ regarding the distribution of these innovation activities across developed countries. It emphasises the important fact that the propensity and intensity of investment in innovation is not uniform across an economy, but varies considerably across categories such as industry and firm size.[6] These, in turn, generate enormous diversity of workforce skills required to implement these activities. Finally, it draws on some key concepts from the innovation studies literature to describe different processes of innovation and how they affect the demand for different skills. These processes include, for example, the distinctions between radical and incremental innovation, learning by doing and using and the innovation product cycle. A key message to emerge from this analysis is that there is no ‘one size fits all’ model for undertaking innovation or for the type of skills required for successful innovation.

6 ‘Propensity’ measures the proportion of firms within a given category undertaking innovation. ‘Intensity’ measures the ratio of innovation expenditures to value added. In this paper the ratio is derived by taking each industry’s share of total innovation and R&D expenditures to its share of total value added or GDP.

2.3.1 What is innovation?

The conceptual framework for data collection on innovation defines this activity as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (*Oslo Manual*, third edition, OECD and Eurostat, 2005: 46).

A product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics. Product innovations can utilise new knowledge or technologies, or can be based on new uses or combinations of existing knowledge or technologies. Product and/or service innovation entails activities such as design, research and development, acquisition of patents, technology licenses, trademarks, and tooling-up and industrial engineering.

A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software. Process innovations can be intended to decrease unit costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products.

A marketing innovation is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. Marketing innovations are aimed at better addressing customer needs, opening up new markets, or newly positioning a firm's product on the market, with the objective of increasing the firm's sales.

An organisational innovation is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations. Organisational innovations can be intended to increase a firm's performance by reducing administrative costs or transaction costs, improving workplace satisfaction (and thus labour productivity), gaining access to non-tradable assets (such as non-codified external knowledge) or reducing costs of supplies.

Research and development

Research and Development (R&D) is a part of innovation activity. The conceptual framework for data collection on R&D defines this activity as 'creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications' (*Frascati Manual*, 6th edition, OECD 2002b).

R&D entails three activities:

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. [7]

[7] The Australian Bureau of Statistics (2005b) differs from the *Frascati Manual* (2002) in subdividing basic research into 'pure' and 'strategic' basic research. The former is 'experimental and theoretical work undertaken primarily to acquire new knowledge without a specific application in view. Pure basic research is carried out without looking for long-term benefits other than the advancement of knowledge' Strategic Basic Research 'is directed into specified broad areas in the expectation of useful discoveries. It provides the broad base of knowledge for the solution of recognised practical problems'. This is relevant as Australian R&D data is used in this chapter.

Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.

Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed (OECD 2002b: 30).

2.3.2 Innovation activity and skills

Official surveys of innovation across the OECD reveal large and systematic differences in the propensity of firms to innovate and the intensity of their innovation activity. It must be acknowledged however, that there are limitations to the use of these surveys to analyse skills. The principal limitations are that such surveys collect only very aggregate data on skills and there may not be a direct linkage between the type of innovation activity and level of innovation expenditure undertaken by an industry on the one hand, and the employment of people and skills within the industry on the other. This arises because some innovation activities, such as design or patenting, may be funded by one industry, say manufacturing, but their undertaking may be outsourced to another industry, say Business services, which includes industrial design consultancy and legal firms. Although these complex input-output relations make it difficult to infer the skills and occupations involved in innovation in a specific industry, the official surveys do provide a clear insight into the breadth of skills required for innovation at an economy-wide level. The following examples are taken from Australia using statistics from recent official innovation surveys of private businesses, though it is crucial to note similar patterns of diversity apply across OECD countries.

Whilst the benefits for firms engaging in innovation have long been recognised it is also the case that at any point in time only a minority of firms actively pursue technological or non-technological innovation across developed economies (Table 1). For example, over the three-year period 2001-03 in Australia just 34.8% of firms undertook any form of innovation. This is despite the broad scope of activities included under the definition of innovation and the generous time period over which such activities could occur. (Respondents to the innovation survey were asked if they had undertaken any of the defined innovation activities at any point in time over the three years).[8] This average however, hides considerable diversity in the propensity to innovate across industries. Just over 50% of firms in Electricity, gas and water and Communication industries invested in innovation. This is nearly double the proportion of firms in the Accommodation, cafes and restaurants industry, with just 26.5% of such firms innovating. Just over 30% of firms in Construction and Retail innovated.

8 Moreover, nearly half of all firms that do not innovate report that there are no barriers to their undertaking innovation (Table 4).

Table 1. Distribution of expenditure on innovation and R&D by industry. 2002-03

	Proportion of businesses in each industry innovating* %	Proportion of total Innovation expenditures undertaken in each industry** %	Proportion of total R&D expenditures undertaken in each industry%	Industry share of GDP*** %	Industry innovation intensity (Ratio of columns a to c)****	Industry R&D intensity (Ratio of columns b to c)****
		Col. (a)	Col. (b)	Col. (c)		
Mining	30.9	3.4	9.3	4.5	0.8	2.1
Manufacturing	45.5	27.1	44.3	11.5	2.4	3.9
Electricity, gas & water	50.8	1.9	1.0	2.3	0.8	0.4
Construction	30.7	5.3	2.2	5.8	0.9	0.4
Wholesale	42.9	22.0	5.2	5.0	4.4	1.0
Retail	31.4	3.4	.3	5.9	0.6	0.1
Accomm., cafes & restaurants	26.5	1.3	n.p.	2.1	0.6	n.p.
Transport & storage	34.9	3.7	.5	4.4	0.8	0.1
Communication	51.1	5.9	6.0	2.8	2.1	2.1
Finance & insurance	44.3	12.6	9.2	6.7	1.9	1.4
Property & business services	31.7	11.5	20.9	11.7	1.0	1.8
Cultural & recreation	36.7	1.8	.4	1.3	1.4	0.3
Total	34.8	100	100			

Source: ABS 2005a: Tables 1.1, 1.4; ABS 2005b Table 1.3; ABS 2005c: Table 11. *Estimates of the proportion of businesses innovating covered the three calendar years 2001 to 2003. Expenditure data was for the 2002-03 financial year only ** Excludes R&D *** Note the percentages do not sum to 100 as some industries, such as Agriculture, Government Administration, Education, Health, and Personal Services are excluded. **** A ratio of less than 1 indicates that the industry's share of total innovation or R&D expenditures is less than its share of GDP. Data for Accommodation, cafes & restaurants is not published due to confidentiality reasons.

Table 2. Composition of innovation expenditures by industry, 2002-03. Percentage.

	Mining	Manufac.	EGW	Construc.	Wholesale	Retail	Accomm. & rest'ant	Transport & storage	Commun'n	Finance & insurance	Property & business services	Cultural & recreation	Total
Product/service innovation *	**47.1**	**71.4**	**20.0**	**50.0**	**82.8**	**50.0**	**77.8**	**60.0**	**77.8**	**60.0**	**53.3**	**75.0**	**64.7**
Acquisition of machinery	41.2	33.3	10.0	16.7	6.9		50.0	53.3	70.4	26.7	20.0	50.0	23.5
Acquisition of licences, patents, etc							5.6		3.7	6.7	6.7		5.9
Training related to new product, service or process				8.3			5.6			6.7			
Marketing		19.0		16.7	13.8	25.0	11.1	6.7	3.7	13.3	6.7	12.5	11.8
New design work		9.5			3.4					6.0	6.7		5.9
Other	5.9	4.8			62.1				3.7		13.3	12.5	17.6
Process innovation	**47.1**	**23.8**	**70.0**	**33.3**	**13.8**	**25.0**	**11.1**	**33.3**	**18.5**	**13.3**	**26.7**	**25.0**	**23.5**
Non-technological innovation	**5.9**	**4.8**	**10.0**	**16.7**	**3.4**	**25.0**	**11.1**	**6.7**	**3.7**	**26.7**	**13.3**		**11.8**
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: ABS 2005a. Excludes R&D. *For some industries, such as Manufacturing, Construction and Electricity, gas and water, not all expenditures on product/service innovation were fully enumerated in the original data so that the components of this form of innovation do not sum to the total.

There are also marked differences in innovation intensity across industries. Wholesale industry has the highest innovation intensity rating of 4.4. (Meaning that its share of total innovation expenditure is 4.4 times its share of total GDP). Retail and Accommodation, café and restaurant industries have the lowest innovation intensity with a rating of just 0.6. In other words, the innovation intensity of Wholesale is over seven times greater than in these latter two industries. There is a similar large variation in the intensity of R&D expenditures across industries. As noted above, R&D is an important component of innovation activity. Manufacturing has the highest R&D intensity rating of 3.9. (Meaning that its share of total R&D expenditure is 3.9 times its share of total GDP). Two industries, Retail and Transport and storage have an R&D intensity rating of just 0.1. (R&D data for the Accommodation, café and restaurant industry is not available due to confidentiality reasons.)

Other business characteristics also influence the propensity and intensity of innovation. For example, just 30% of firms with less than 20 employees innovated compared to 61% of firms with more than 100 employees. Firms with more than 100 employees represent only 7% of all innovating firms but account for 56% of all innovation expenditures. Majority foreign owned firms are nearly twice as likely to innovate as locally owned firms. This arises from the fact that foreign owned firms are larger on average than local firms and are concentrated in industries such as manufacturing, communications, property & business services and finance & insurance in which innovation in products/services and processes are the bases of competition.

There are also marked differences in the composition of innovation activities across industries (Table 2). For example, over 80% of the total innovation expenditure of the Wholesale industry is directed at improving or introducing new products or services compared to just 20% by the Electricity, gas and water industry. Within the category of product and service innovation there are also marked differences in the way industries undertake this innovation. For example, Wholesale spends just 6.9% of its total innovation funds on the acquisition of machinery, compared to over 70% by the Communication industry. Organisational innovation is especially important for Retail and Finance & insurance industries accounting for around one quarter of their total innovation spending, compared to just 3.4% by Wholesale. Variation in the methods used by industries to innovate reflect a broad range of factors such as differences in their production technologies, the nature of the product or service they produce, degree of capital intensity and bases of competition.

These marked variations in the propensity and intensity of innovation, and in the range of activities undertaken when firms do innovate, demonstrate that the demand for skills for innovation is not uniform across the economy and, by implication, that there is enormous variation in the type of skills required for innovation across industries, firm size and ownership structure. For example, the skills required by the Communication industry to undertake its principal innovation activity, namely acquisition of telecommunication equipment, would encompass a broad range of higher-level electronic and software engineering to scan global supply networks and ensure compatibility of new and existing equipment; high-level strategic business planning and finance specialists to ensure the new equipment capacity matches the business model and marketing plans; and tradespeople and technicians to install, operate and maintain the equipment. By contrast one quarter of the Retail industry’s innovation spending is committed to marketing, which requires a totally different set of skills altogether in customer liaison and advertising. Retail and Finance & insurance industries commit around 25% of their innovation funds to non-technological innovation, such as achieving efficiency through organisational restructuring and workforce training. This activity requires expertise in human resources, organisational psychology and adult education.[9]

Other data from the innovation survey point more directly to the diversity of skills required for innovation. Innovating businesses were asked to identify a range of skills and capabilities sought when recruiting people to develop new goods or services or implement new operational or organisational/managerial processes (Table 3). Just under half (47.4%) of all innovating businesses sought additional skills to implement their innovations over the course of the two calendar years 2004 and 2005. Interestingly, just 2.2% of innovating firms recruited scientific personnel for innovation.[10] The skills recruited by the highest proportion of innovating firms were general business (22.6%), information technology (18.2%) and marketing (16.7%). There are large differences in the type of skills sought across industries. For example 43% of Electricity, gas and water firms sought general business skills compared to just 14.9% in Property and business services. Nearly a quarter of innovating Electricity, gas and water firms sought marketing skills which was nearly double the proportion of firms in Transport and storage.

An insight into the relative importance of skills for innovation can also be gained from recent innovation surveys, which also inquired into the barriers to innovation experienced by innovating and non-innovating firms (Table 4). Over one quarter of firms (27.2%) that innovated stated that lack of skilled staff, either within the firm or externally in the wider market, such as that available through consultancy services, was a constraint on their capacity to innovate. Just over one in five firms that did not innovate stated that lack of skilled staff was a barrier to their undertaking innovation. Whilst other factors such as high direct cost, excessive risk and small size of the market were identified as a barrier by a higher proportion of innovating and non-innovating firms, it is clear that lack of skills is perceived as a significant constraint on the capacity of firms to innovate.

9 These results are supported by data on the type of skills recruited by firms to undertake innovation (Table 3).

10 This result is consistent with other results from innovation surveys which emphasise the incremental nature of most innovation. However, this is not to underplay the importance of scientific skills in innovation.

Table 3. Innovating businesses recruiting skills for innovation.
Percentage. 2004 and 2005 (a) (b) (c).

	Mining	Manufac.	EGW	Construc.	Wholesale	Retail	Accomm. & rest'ant	Transport & storage	Commun'n	Finance & insurance	Property & business services	Cultural & recreation	Total
Engineering	37.9	20.2	48.6	18.5	10.2	0.8	6.0	5.9	9.0	1.6	6.7	8.5	9.3
Scientific	5.1	5.6	16.8	n.p.	4.8	0.0	0.0	0.3	n.p.	0.5	2.2	2.5	2.2
Marketing	18.4	14.7	24.8	13.7	16.6	16.1	24.2	12.7	21.8	18.6	15.8	23.7	16.7
Information technology	18.4	16.7	33.8	15.2	21.2	6.9	10.2	20.6	48.5	21.0	26.8	33.3	18.2
Product management	16.4	13.4	11.8	7.9	12.7	8.0	18.4	11.2	14.5	14.7	3.8	13.0	10.1
General business	21.9	18.0	43.0	32.2	30.0	21.7	30.6	18.3	28.5	30.9	14.9	21.5	22.6
Other	4.8	5.3	6.9	3.3	1.4	4.1	4.1	11.1	6.6	12.6	6.8	14.1	5.4
Total innovating businesses that recruited	57.2	48.3	72.5	46.4	53.9	34.2	55.0	44.7	67.9	56.8	47.1	58.5	47.4
Total innovating businesses that did not recruit	42.8	51.7	27.5	53.6	46.1	65.8	45.0	55.3	32.1	43.2	52.9	41.5	52.6

Source: ABS (2006b) (a) Calendar years. (b) Businesses could identify more than one skill sought. (c) Proportions are of innovating businesses in each industry reporting recruitment of specific skills to develop or implement innovation.

Table 4. Barriers to Innovation, 2004 and 2005. Percentage (a) (b).

Barriers	Innovating firms	Non-innovating firms
Cost related barriers	58.4	36.5
Any market related barriers	36.7	27.0
Lack of skilled staff	27.2	20.6
Other barriers	4.6	4.9
No barriers to innovation	26.7	48.1

Source: ABS (2006b) (a) Calendar years. (b) Businesses could identify more than one barrier.

Other data sources and methodologies not only confirm the variety of skills required for innovation but also suggest that there is only a weak association between various measures of skill, such as occupation or education, and the intensity of innovation of industries. One study grouped industries into three levels of innovation intensity, high, medium and low, using a composite index of innovation activity (Toner, 2004).[11] It then examined the extent of similarity of occupational structure and educational attainment of the workforce within and between the three levels.

Taken as a whole innovation intensive industries had a higher share of managers, professionals, tradespersons and advanced clerical occupations than the medium- and low-innovation-intensity industries. However, when the occupational structures of the four discrete industries comprising the high innovation intensity category were separately analysed it was found that:

> *There is very considerable diversity in their occupational structures. Indeed, the degree of variation in the occupational structure across these four industries is as great as that across all industries. In other words, taken collectively, there are significant differences in the occupational structure between innovation and non-innovation-intensive industries, although as separate industries, these differences become much less distinct. The fact that the association between occupational structure and innovation intensity of industries depends on the level of analysis undertaken suggests that the association is not robust (Toner, 2004: 76).*

It must also be emphasised however, that the innovation-intensive industries, and many less innovation intensive industries, did experience a significant increase in skill level over time.

A similar and related finding applies to educational attainment. In aggregate the share of persons in high-innovation industries with a degree or post-graduate qualification is around 33% higher than in medium- or low-innovation industries. (Around 22% of the workforce compared to around 16% for medium- and low-innovation intensive industries). This largely reflects differences in occupational structure between the three broad categories of innovation intensity with the most innovation-intensive level having a higher share of managers and professionals. However, it was also the case that variation in educational attainment within the four high innovation intensity industries is as great, if not greater, than that across the three levels of innovation intensity. For example, the share of persons with degrees or post-

11 The classification comprised *high-innovation industries:* mining; manufacturing; property and business services and communication services. *Medium-innovation industries:* electricity, gas and water; wholesale trade; finance and insurance; and transport and storage. *Low-innovation industries:* personal services; retail trade; cultural and recreational services; health and community services and construction.

graduate qualifications in Property and business services was over one-third compared to around 11% for manufacturing, despite both industries being classified to the high-innovation-intensity level (Toner, 2004: 58). Industries such as Electricity, gas and water and Cultural and recreational services, classified to medium- and low-innovation intensity respectively, had a workforce whose share of persons with degrees or higher qualifications was more than double that in manufacturing.[12]

This section has demonstrated the following. First, at any point in time a majority of firms are not actively engaged in innovation. Second, there are very large variations across industries and other business characteristics, such as firm size and ownership structure, in the propensity and intensity of innovation. Both of these influences have important implications for the aggregate demand for skills to undertake innovation within an economy. That is to say, the industrial structure is a major determinant of the demand for skills and change in the demand for skill over time. Third, there is significant variation in the specific activities or processes firms use to undertake innovation. There is variation in the type of innovation activity not only across industries but also across other business characteristics such as firm size and ownership structure. Each industry and firm undertakes the process of innovation in its own unique way. Fourth, given the great variation in specific innovation activities across industries and firms there is a corresponding variation in the skills, occupational structure and educational attainment in their workforce. Finally, it is clear that occupations other than S&T are essential to successful innovation by industry.

2.3.3 Occupational structure of the R&D workforce

R&D is a key element in innovation but, as with the study of innovation, most analyses of the R&D workforce have focussed primarily on the university educated S&T workforce (Shapira, 1995). Again, as with the broader concept of innovation, there is great diversity in the range of activities undertaken within R&D and, consequently, considerable diversity in the occupational structure of the R&D workforce. This section will demonstrate that there are large differences in the use of broad occupational groups across R&D activity and that these are systematically related to the type of R&D on which they are engaged.

The great bulk of business R&D expenditure is devoted to Development, not Research; that is to say, it is directed not at fundamental or basic research but to improve existing products, services and production methods (Table 5).

Table 5. Expenditure on R&D in business. Australia. 2005-06

Type of R&D activity	Proportion of total R&D expenditures %
Pure basic research	0.7
Strategic basic	4.1
Applied research	32.9
Experimental development	62.4

Source: Derived from ABS 2007: Table 8. *Note: As mentioned in footnote 7, this four way classification is used by the Australian Bureau of Statistics and differs from the* Frascati Manual (2002).

12 The high level of aggregation in this analysis undoubtedly masks considerable variation if a finer sub-industry level of analysis was undertaken.

As part of the regular collection of data on R&D in firms in Australia and the OECD, information is sought on broad occupational categories of labour involved in R&D. The *Frascati Manual* distinguishes three types of labour involved in R&D: researchers; technicians and other supporting staff. Researchers are professional occupations such as scientists and engineers and research managers. The categories of interest for the purpose of this study are technicians and other supporting staff. The latter category includes skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects.

Surveys of business R&D indicate that 46% of total person years in 2005-06 involved in R&D in Australia are classified as VET occupations, that is, Technicians and Other Supporting (Table 6). A similar result applies across developed economies.

Table 6. Distribution of human resources devoted to R&D by business. 2005-06

Type of labour	Proportion of total person years devoted to R&D %
Researchers	53.9
Technicians	31.5
Other supporting	14.6

Note: A person year is full-time equivalent employment over one year.

Source: Derived from ABS 2007: Table 17.

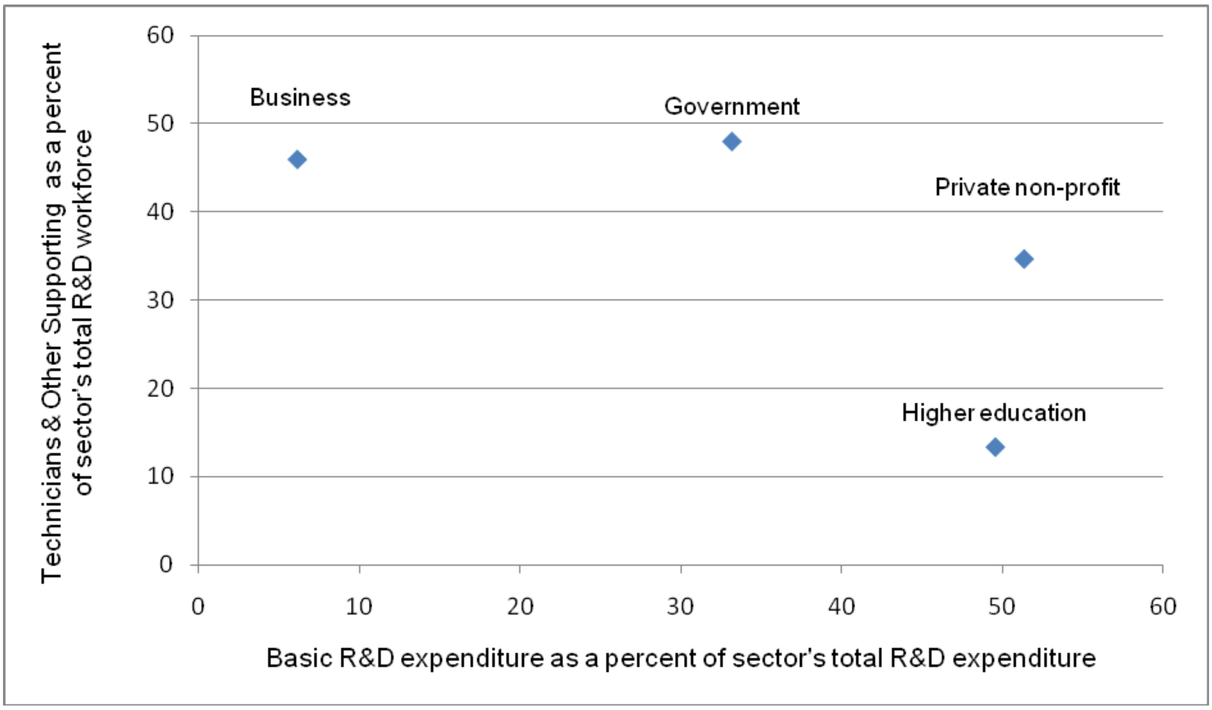
In the European Union 44.6% of persons engaged in business R&D in 2005 were classified as Technicians and Other Supporting (OECD, 2006a: Tables 27, 30). This result should not come as a surprise as it was shown earlier that the great bulk of business R&D expenditure is devoted to Development not Research. Such business Development activity is directed at generating goods and services for sale, not at fundamental scientific inquiry. Developing goods and services for sale involves for example, creating prototypes, and adapting existing or new equipment and software to new or improved products and services. Such activities are a key function of trade and technician occupations.

Across all sectors that undertake R&D, that is business, government, higher education and private non-profit organisations, technicians and other supporting occupations comprised 31.7% of all person-years devoted to R&D in 2004-05 (ABS, 2006c: Table 14).

An insight into the ‘division of labour’ between researchers on the one hand and Technicians and Other Supporting occupations on the other is provided in Figure 1.

There is generally an inverse relationship between the share of research expenditure on basic research and the share of Technicians and Other Supporting occupations in the total R&D workforce. For example, only around 5% of business R&D is devoted to basic research and 46% of this sector’s workforce is classified as Technicians and Other Supporting occupations. Conversely, just over 50% of the higher education sector’s R&D is classified to basic research and just 17% of its workforce is comprised of Technicians and Other Supporting occupations. These results are taken to provide support for the contention that Technicians and Other Supporting occupations are involved in particular in incremental R&D that is directed primarily at the introduction of new products, services and production processes to market.

Figure 1. Relationship between type of R&D expenditure and composition of R&D workforce 2004-05



Source: Derived from ABS, 2006c, Tables 6, 14.

2.3.4 Radical and incremental innovation and workforce skills

Another perspective on different forms of innovation and their implications for workforce skills is provided by examining the distinction between radical and incremental innovation. Innovation is classified into two broad types of activity, radical and incremental, depending on the processes used and outcome of the activity. Radical innovations give rise to major technological, economic and social change. Examples of radical innovation include the development of agriculture, printing, railways, electricity, motor vehicles, the transistor, contraceptive pill and atomic power. The following sets out the principal properties of radical innovations. Radical innovations typically:

- Are subject to great uncertainty, not only in the course of invention, but also in terms of the size of the potential market or even the existence of a market for the new product, service or process (Rosenberg, 1994: 23).

- Take a long time for the market opportunities to be exploited, largely because the original innovation requires a series of subsequent complementary innovations, often taking decades to achieve (Rosenberg, 1994: 4).

- Are 'disruptive' - in Schumpeter's famous description they generate "gales of creative destruction" by making existing products, production systems and skills technologically redundant.

- Affect multiple industries, if not whole economies.

- Over the course of the last century are primarily the product of massive government and/or private investment in basic and applied R&D and, consequently, the product of high-level science and engineering skills (Rosenberg, 1994: 20).

By contrast incremental innovations "involve endless minor modifications and improvements in existing products, each of which is of small significance but which, cumulatively, are of major significance" (Rosenberg, 1994: 14-15). Incremental innovations typically:

- Use existing technologies and standards to effect improvements to existing products and services.

- Have predictable development costs and market potential.

- Can be undertaken by a broad range of businesses and firms as it does not necessarily require large investment to develop or implement.

- Are the principal source of productivity growth in economies as new applications are found for existing technologies and as these undergo gradual optimisation (Scott-Kemmis, 2004: 70).

- Are often inspired and developed by direct production workers as users or producers of a good or service or the result of improvements suggested by final consumers of goods and services (von Hippel, 1988, 2005). Two leading figures in innovation research Carl Dahlman and Richard Nelson, for example, find that the 'cumulative productivity impact of small incremental changes that are usually undertaken on the shop floor can be much greater than initial introduction of a major technology' (Dahlman and Nelson, 1995: 95).

A key implication of the prominence given to incremental innovation is that it has largely displaced the earlier 'linear model of innovation' in which innovation was assumed to proceed from basic scientific research to applied research and then into production and diffusion (Godin, 2005).[13] Rather, attention has focussed much more on the drivers of incremental innovation and the importance of widely distributed skills in the workforce to identify and adapt current technologies. On this last point Scott-Kemmis (2004: 70) has argued that:

> *"While not diminishing the importance of breakthrough innovation or of local discovery, the majority of innovation is incremental, involving improvement in products, processes, methods and so on…Hence broadly distributed capabilities are vital and investment in human resources is the essential foundation for innovation."*

A key part of the direct production workforce is trade and technician occupations. They play a critical role in incremental innovation given that their training and function in the workforce entails the *generation, design, installation, commissioning, adaptation, maintenance and diffusion* of new and existing technologies (Toner, 2004). (A more detailed discussion on the specific contribution of these occupations to innovation and how this is mediated, for example by the quality of their training, is provided in section 3.2).

Ensuring broadly distributed capabilities across the workforce depends on high rates of participation in quality initial education and training and the efficiency of technology diffusion within a country, region or firm. "Technology diffusion involves the dissemination of technical information and know-how and the

13 Godin (2005) argues that the persistence of the linear model in policy circles, despite its well-demonstrated weakness, is in part due to the categories employed in official R&D statistics which imply a seamless transition from 'pure basic research' to 'experimental development'.

subsequent adoption of new technologies and techniques by users… In many cases, diffused technologies are neither new nor necessarily advanced, although they are often new to the user" (Shapira and Rosenfeld, 1996). Improved technology is diffused in embodied form through enhanced equipment and software or through learning from education, training and experience.

Evidence for the centrality of incremental innovation and workforce capacity for technology adoption and diffusion is provided in surveys of innovation across OECD countries. These establish that the great bulk of innovation by firms comprises the application of production processes, products and services that have already been implemented in other branches of the business or by competitors. In other words, most innovation comprises the diffusion and adaptation of existing knowledge. For example, 1% or less of all innovations introduced over calendar years 2004 and 2005 in Australian business were deemed by the firm introducing them to be 'new to the world' (Table 7).

Table 7. Novelty of innovation.

2004 and 2005

	Proportion of firms reporting novelty of innovation			
Type of innovation	New to business %	New to industry %	New to Country %	New to world %
Product/service	74	20	15	>1
Process	87	11	4	1
Organisational	94	6	1	>1

Table 2.13 Note the rows do not sum to 100% as firms could provide multiple responses to each question if they were unable to allocate the degree of novelty of an innovation to a single category.

Source: ABS, 2006b.

2.3.5 Learning by doing and using

Learning by doing and using are the principal drivers of incremental innovation. In almost all fields of production of goods and services, the repetition of production tasks leads to a gradual improvement in the efficiency of production processes and product/service design and performance. The importance of such 'learning by doing' processes has long been recognised, as has the central place of direct production workers in innovation as sources of work-based learning (Landes, 1972).

Such work-based learning is also central to what is known as 'learning by using' or, more broadly, user-producer interaction. This form of learning entails the flow of information from the user of products or services to the producer of these products and services (Rosenberg, 1982: 121–22; von Hippel, 1988; 2005). Users of capital, intermediate or consumer goods or services provide regular feedback to the producers of these goods and services, communicating suggestions for design and other changes to extend their range of uses, improve their performance or reduce their cost.

It has been argued that learning by doing and using, especially amongst direct production workers, is based on the application of 'practical knowledge'. This is contrasted with "theoretical knowledge…which is about pursuit of the truth" and employs a "rule based, instrumental or reductionist logic" (Nyhan, 2002: 112). Practical knowledge is:

"Application-oriented…Unlike scientifically and theoretically generated knowledge that orients itself on criteria such as theoretical relevance and universality, practical knowledge is generated in application contexts of new technologies and obeys validity criteria such as practicability, functionality, efficiency and failure-free use of a given technology…[These are derived from] accumulated experience and well-established and proven and tested routines for solving technical problems" (Hirsch-Kreinsen, 2008: 27).

Learning by doing and using are the result of the accumulation of knowledge generated by experience in the production process or in the use of goods and services. The success of this accumulation depends critically on five factors:

- Firstly, the type of work organisation employed in production, especially the capacity of management to motivate production workers to provide feedback.

- Secondly, establishing communication between producers and users.

- Thirdly, it depends on the willingness of management to act on this information.

- Fourthly, the competitive strategy of the producing firm and specifically the extent to which it competes on quality, customisation to client need, design and achieving cost reductions through innovation and capital investment. (The alternative is to compete on price achieved for example through mass production techniques and low labour costs).

- Finally, it depends on a wide distribution of technical competence within the producing firm's workforce and across the users of its goods and services.

2.3.6 Innovation, product cycles and skills

It has been observed that there is a systematic relation between product and technology cycles and the demand for skills. The use of a new production process or introduction of a new product or service by a firm can result in job tasks becoming less well-defined with attendant uncertainty about effective task performance. Uncertainty regarding operating procedures and expected outcomes requires higher-skilled workers with greater understanding about the production process and capacity to deal with unanticipated results. As the behaviour and properties of products, services and processes are better understood they become codified in standard operating procedures that can be performed by less skilled workers. There are many examples in industries as diverse as chemicals, computing and atomic power, where initial production required highly qualified experts with advanced degrees, but which subsequently use labour that may need only in-house training (Kim, 2002: 101). Similarly, for firms with products or services that are technologically obsolete or have achieved 'maturity' in their market share, there may not be an incentive to devote scarce resources such as higher-level marketing or product development skills, to extend their commercial life (Flaherty, 2000).

2.3.7 Innovation in service industries

The innovation studies literature has highlighted the importance of services in developing and diffusing innovation and the different approaches to innovation between services and manufacturing. A particular interest has been so-called knowledge intensive service activities such as engineering and computer consultancies, industrial design, accounting and legal services (OECD, 2006b). These activities are particularly skill-intensive in that their workforce is predominately comprised of professional and managerial occupations and the level of educational attainment is correspondingly high.

Many other service activities however, are much less skill-intensive, but may, nonetheless be the source of economically important change. For example, the phenomenal growth of franchising over recent decades does not typically entail the delivery of highly innovative services. Frequently quite mundane activities are involved such as lawn mowing, car repair, bread making or fast food. Franchising of such activities is successful primarily because of organisational innovation. In essence franchisees pay a fee for service for access to the organisational innovation, provided through initial training and on-ongoing support from the franchisor. In the fast food industry, for example, a low-skill workforce and high labour turnover mean that firms have to adopt a particular method of skills training and approach to productivity improvement. Minimal training is provided to service operatives, but delivery of the service or product is tightly specified. Tightly specified and closely monitored ingredients from a small number of suppliers, such as bread rolls, salad and meat, provide uniform inputs, thereby minimising a potentially important source of product variation. A key role for the franchisor is to ensure uniformity of product and service delivery across the franchisee chain. However, an important by-product of this close monitoring is that the franchisor can detect minor planned innovations or fortuitous deviations from the approved methods of product or service delivery that sporadically arise across the chain of franchisees. The role of the franchisor is to assess these deviations and, where they are deemed to enhance productivity or quality, convert this valuable, but often tacit knowledge, into codified practice by embedding the improvement in new organisational routines and standard operating procedures. These are then diffused across the chain (Argote and Darr, 2000).

2.4 Benefits of higher skills for innovation

The previous section identified a range of arguments put forward to explain rising interest in the subject of skills and innovation. This section summarises the main arguments put forward in the literature to explain the contribution of skills to innovation. Whilst there are several distinct disciplinary approaches to the study of skills and innovation (outlined in Chapter 3) the arguments regarding the benefits and contribution of higher skills to innovation are generally common across these approaches.

2.4.1 Accelerating technical change

There is argued to be a virtuous circle between increased investment in workforce education, investment in knowledge creation, such as fundamental research, and an increased rate of implemented technical change. The principal mechanism in this virtuous circle is the unusual properties of knowledge.[14] Firstly, unlike standard economic goods, knowledge, conceived as a factor of production, is not subject to diminishing returns and does not depreciate as each increment in knowledge adds to the total stock of knowledge.[15] Secondly, knowledge is non-rivalrous in that it can be employed by multiple producers simultaneously without affecting producers' costs. Another aspect of its non-depreciation and non-rivalry is that having been acquired by a producer it can continue to be used indefinitely so that its marginal cost

14 The following arguments are well known and are mentioned in summary form only. A useful account is provided in Dowrick (2003).

15 Even knowledge, such as outmoded scientific theories which have been 'falsified', or failure in the market of a new good or service, act to preclude scientists and entrepreneurs from the pursuit of 'dead-ends'. Flaherty (2000) uses the example of quality systems to describe how knowledge is additive-acquiring knowledge about one aspect of a production system reduces the cost and effort of acquiring additional information about the system. For example, one objective of quality systems is to increase conformity of output with specifications so that 'as process variability decreases and…knowledge increases, it becomes easier to learn almost anything else about a process…increasing conformance quality increases the effectiveness of efforts to acquire further process knowledge of all sorts…reduced variance increases the power of subsequent hypothesis tests, or reduces the sample size needed to attain a given power' (Flaherty, 2000: 106).

effectively falls to zero. Knowledge is also non-excludable in that there are either no limits imposed by property rights on the use of knowledge or these rights are of finite duration (Arrow, 1962a).[16] Thirdly, education, knowledge and skills have the property of a network externality, that is to say, the value in acquiring knowledge by any one user increases at a rate proportional to, or even greater than, the rate of increase in the number of other users. In other words, the productivity of any worker is enhanced not only by their individual level of skill but also by the average skill level amongst their fellow workers. Fourth, knowledge is a joint-product of production: expanding output also increases the accumulation of knowledge through learning by doing (Arrow, 1962b). Knowledge is thus both an input and output of production and innovation.

In summary, these various properties of knowledge have been used to argue that the growth of knowledge is subject to increasing returns, that is, "knowledge acquired per unit of time is greater if the stock of publicly available knowledge is larger" (Prescott, 1998: 541). In addition, the growth of knowledge raises the productivity of capital investment when it is embodied in more recent vintages of physical capital goods and software. In turn, this is claimed to account for the presence of increasing returns to capital investment at an economy-wide level, as evidenced by the long-run increase in the capital-labour ratio (Romer, 1994).

These various properties of knowledge have also been used to explain important long-run trends, especially rising workforce educational attainment, rising R&D intensity (R&D as a share of value added) and increase in the breadth of technologies subject to R&D by large individual firms. Firstly, growth in the 'volume' of knowledge requires ever higher workforce skills to identify, assess and implement new knowledge. Secondly, the complex input-output relations that typify large firms require them to keep up to date not only with technological advances in inputs from a multiplicity of supplier firms, but also to constantly devise new uses and improvements to their own products and services which are also typically used as inputs by a multiplicity of firms across many industries. One measure of this tendency is the growing propensity for large firms to engage in R&D and patent activity across a range of industrial classifications that is much wider than the industrial classification of the products or service they make (Patel and Pavitt, 2000).

> "[L]arge firms and the products they make depend on many fields of technological competence, the number of which is increasing over time with the widening range of technological opportunities emerging from improvements in computing and other technologies. In order to assimilate this range of emerging technologies, large firms simultaneously increase their internal competencies, form alliances with external sources, and *increase* their overall R&D expenditures" (Patel and Pavitt, 2000: 330).

[16] A great deal of knowledge may well be 'free to use' but this does not imply that knowledge is a 'free good'. As Callon (1994) has shown there are degrees of non-rivalry and non-excludability and often significant private and public investments required to make knowledge non-rivlarous and non-excludable. The most important example of these private and public investments is education. Callon also makes the point that whilst knowledge does not 'wear out' or depreciate in a manner analogous to capital equipment there are however considerable costs in its storage. Arrow deals with 'knowledge' at a very high level of abstraction, which also hides the fact that much knowledge is 'sticky' in that it is not easily transferred. For example knowledge may be sticky because it is context dependent, say the operation of a unique industrial process or the information may be only tacitly understood.

2.4.2 Adapting to technical change

A related, but somewhat different argument relates higher skills to a faster rate of technical change, in that empirical studies show "that more highly-educated individuals tend to adopt innovations earlier and implement and adapt them sooner than less-educated individuals" (Kim, 2002: 92). This applies both to the consumption of new technologies, for example in the home, and in production. More educated and skilled workers are argued to have greater 'functional flexibility' in that their greater stock of knowledge increases the rate at which they learn and develop higher order problem solving skills. This greater functional flexibility is also argued to be important for innovation at a macro-economic level, as more educated persons are better able to cope with rapid structural change induced, for example, by international trade or innovation. An indicator of this is the strong positive relation between educational attainment and labour force participation and strong negative relation between higher educational attainment and rates of unemployment (HM Treasury, 2004: 8).

2.4.3 Complementarity of education, training and innovation

It is well established that the propensity of firms to provide employer-funded training and the intensity of this training increases markedly the higher the initial educational attainment and prior training of its workforce (Arulampalam and Booth, 1998; Wolbers, 2005).[17] For example Draca and Green's (2004) study of the Australian workforce in the 1990s finds the probability of workers with degrees or higher qualifications receiving employer funded training is close to two-thirds higher than persons whose highest educational attainment is a basic vocational qualification and around 50% higher than persons with trade qualifications or who had completed high school. The number of hours of training received by managers, professionals and associate professionals is nearly three times more than persons in clerical occupations and more than five times that of tradespeople. They conclude that "there are substantial complementarities between education and training" (Draca and Green, 2004: 622). Similar magnitudes are reported in Arulampalam and Booth's (1998) study of the UK labour market. This complementarity is attributed to a range of factors that make it more profitable for employers to invest in training persons with higher initial education, such as the more educated having better learning skills and lower marginal training costs compared to those with less education. Obviously, educational attainment and occupation are also correlated and there are plausible reasons why managerial, professional and associate professional occupations receive more workplace training than say, labourers or truck drivers. For the former group the rate of change in their knowledge base can be rapid and on-going professional development may also be mandatory to maintain membership of professional associations.

Further there is an association between the propensity of firms to innovate and the probability of them providing workplace training. There are two major reasons why this should be so. Firstly, the characteristics that are positively associated with a high propensity to undertake innovation are also associated with a high propensity to provide employer-funded training (Toner *et al.*, 2004). These characteristics include, for example, large firm size; foreign ownership; high capital intensity, especially in machinery and software and industry classification. (Industries such as property and business services, manufacturing and telecommunications have a high propensity to both innovate and train, whereas other industries such as construction and retail have a low propensity for both activities). Secondly, when a firm introduces a new product, service, production process or organisational change, new workforce skills are often required.

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17 Propensity to train is the proportion of all firms in a given category, such as industry or firm size, that provide workforce training. For firms that do train intensity is typically measured as total training costs as a proportion of total sales or value added.

This complementarity of education, training and innovation suggests a virtuous circle whereby a workforce with a higher initial level of education stimulates employers to further develop their productive capacity through training and both of these improve the capacity of the workforce to deal with technical change.[18] Conversely, persons with low educational attainment are much less likely to participate in either employer-sponsored training or invest in their own training (HM Treasury, 2004: 26). A vicious circle is evident whereby low initial educational attainment constrains further acquisition of knowledge and capacity to engage in innovation.

2.4.4 Complementarity of capital investment and skills

The complementarity of human and physical capital can correctly be regarded as a subset of the wider topic of education, training and innovation discussed above. Nevertheless, its importance in the literature warrants separate exposition. The virtuous circle between human and physical capital is evident in the long-run increase in the capital-labour ratio where the quantity of capital per worker has increased alongside an increase in the 'quantity and quality' of labour, with the latter measured in terms of rising rates of school and post-school education. Rising levels of capital per worker and new technologies embodied in capital equipment and software are a critical input into innovation as they permit the introduction of new and improved products, services, and production processes. In turn the complementarity of higher capital investment per worker and improvements in the quality of labour suggest that more skilled labour is necessary to achieve the productive potential of new capital investment.

There is a range of evidence for such complementarity including statistical studies where the level or growth rate of per capita income across a large pool of developed and developing countries is regressed against the level or rate of growth of the stock of physical and human capital (World Bank, 1993). Other studies have focussed on differences across developed economies. For example, during the 1990s capital per worker in the United Kingdom was around one-third lower than in Germany and the United States. The stock of human capital in the United Kingdom was also much lower due to higher rates of illiteracy and innumeracy and a lower proportion of the UK workforce with post-school qualifications, especially vocational qualifications. It was argued that "since human capital is complementary to physical capital, one reason why Britain has less physical capital is that its low skills attract less physical capital investment than would otherwise occur" (Layard, McIntosh and Vignoles, 2002: 6).

The complementarity of specific forms of capital investment, especially ICT and human capital, is a particularly prominent theme in the literature under the concept of skill biased technical change. This is discussed in detail in Chapter 3.

2.5 Empirical studies of intermediate workforce skills and innovation

The previous discussion of the benefits of higher skills for innovation was based mostly on quite abstract concepts. However, there is another tradition whose central concern is to examine the effect on economic performance, in terms of the productivity, quality and innovation, of differences in the skills and qualifications of direct production workforces that are to be found across nations. A major focus of these

[18] One study that investigated the links between training, innovation and labour productivity based on large scale surveys of workplaces found that controlling for a broad range of variables, such as industry and firm size, "training and innovation are likely to occur in workplaces experiencing strong labour productivity growth". In turn "labour productivity growth appears to be enhanced by the joint introduction of training and innovation. This is due to the fact that training requires the support of innovation to benefit labour productivity growth. Conversely, introducing innovation in isolation is sufficient to promote labour productivity growth, although its returns are increased by the addition of training" (Laplagne and Bensted, 1999: 46).

studies is the role of workforce skills in explaining differences in the economic performance of the UK and European nations. This section briefly describes those studies that have used 'matched plant' comparisons and differences in the structure of foreign trade to explain the role of workforce skills in innovation.[19]

2.5.1 Matched plant studies

'Matched plant' studies compared firms' performance across a broad range of manufacturing, construction and service industries in the United Kingdom and Europe (Germany, France and Holland) (Prais, 1995; Mason, Van Ark and Wagner, 1996; Anderton and Schultz, 1999; Clarke and Wall, 2000; King, 2001; Clarke and Hermann, 2004). These studies attempt to 'match' plants producing similar commodities across countries and control, where possible, for factors such as differences in capital equipment, product type and regulations that occur across nations. The goal is to thereby eliminate explanatory variables aside from differences in workforce skills. There are large disparities in the skill levels and qualifications of the direct production workforce (production process, trade and technician level occupations) across countries. The United Kingdom in particular has a much higher proportion of the direct production workforce with no qualifications, and those with qualifications are on average at a lower level than in the European workforce. These studies revealed large productivity differences between UK and European firms, for example, in manufacturing of up to 100% and 37% in construction.[20]

A number of factors have been identified which translate national differences in the quality and quantity of persons trained in respective Vocational Education and Training (VET) systems into national differences in productivity, quality and innovation.[21] Firms in countries with a comparatively large proportion of their production workforce with high quality VET qualifications reveal the following characteristics.

Lower defect rates

A significantly higher defect and re-work rate in British plants leads to lower physical output, and hence lower productivity. The lower defect rate is the result of building quality assurance into European production processes. This contrasts with the quality control methods based on the rectification of faults in products at the end of the production line in the British plants. In turn, these differences arise from the employment of more highly skilled and trained production and maintenance staff in European plants and the use of machinery allowing for more automated control of production processes and closer tolerances of work.

Lower ratio of direct to indirect labour

Production in the United Kingdom is characterised by a higher ratio of indirect labour, such as foremen, supervisors and clerical support. This was a function of the higher defect rate and use of quality control systems in the United Kingdom which necessitates more quality checkers. The employment of

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19 Toner (2010) provides a comprehensive summary of the arguments and evidence relating to the role of Vocational Education and Training (VET) system and VET trained workers in innovation.

20 Over the last decade this has changed as UK policy has encouraged the acquisition of formal vocational qualifications by the workforce. Despite conferring some benefits, such as higher rates of employment for holders of these qualifications, the effect of these qualifications on worker productivity, as measured by wage increments to qualification holders, is minimal. This is attributed to factors such as low level of prior educational attainment and limited content of the UK vocational qualifications (Wolf, Jenkins and Vignoles, 2006; Vignoles and de Coulon, 2008; Brockmann, Clarke and Winch, 2008).

21 These are qualifications aligned to the International Standard Classification of Education at level 4 and 5B (UNESCO 1997).

more semi-skilled persons in British plants operating within a Taylorist work organisation, in which individual production employees act with little autonomy, also necessitates layers of supervisors and management to monitor production and directly manage the introduction of new products and processes.

Higher capacity utilisation rates

A higher rate of plant breakdown account for a large part of the productivity differences between British and European plants in the sample. A higher rate of plant breakdown was attributed to inadequate plant maintenance in the British plants, and more specifically, to inadequate preventative maintenance programmes. In turn this is the result of "differences in the skill levels of maintenance teams - though inadequate technical skills at intermediate management level must bear a share of the blame" (Prais, 1995: 71).

Improved scope for product and process innovation

Firms with a higher proportion of more skilled direct production workers, in general, adopted 'flexible specialisation' production methods, which allowed for both the customisation of products and the more rapid introduction of new products. The latter is also commonly referred to as reduced 'cycle times' for the introduction of product innovation; that is, products incorporating new designs, features and components. The use of flexible specialisation production methods reflects much greater use of programmable production equipment and automation of production processes through, for example, automatic loading and transfer devices. This contrasts with a dependence on inflexible mass production methods producing large volume, standardised products. The much lower penetration of programmable production equipment and automation were attributed to a lower level of both production and maintenance skills in Britain.

In the UK construction industry Winch (1998) argued that large contractors, in contrast to their European counterparts, have adopted a cost-cutting approach to productivity through subcontracting, reduced training and labour intensification. By withdrawing from the employment of large numbers of direct production workers head contractors "have abandoned the ability to influence the detailed construction process" on their project sites (Winch, 1998: 541). In so doing head contractors have reduced their capacity to promote innovation and productivity through the dissemination of new technology, quality systems and higher levels of mechanisation (Clarke and Hermann, 2004: 529).

At its most fundamental, the supply of VET skills is influential in determining not only what goods and services are produced in a national economy, but how they are produced. "Firms' product market choices are constrained by the availability of necessary skills" (Estevez-Abe, Iversen and Soskice, 2001: 38-9).

2.5.2 National differences in the structure of exports and imports

A related approach to examining the links between innovation and vocational skills has been to examine cross-country differences in trade performance and differences in the composition of workforce skills (Oulton, 1996). It has been found that countries with an above-average proportion of skilled vocational workers in their workforce have above-average trade performance in products that intensively use these skills. Countries such as Germany and Japan which 'provide broad-ranging, company-based training for particularly high proportions of their workforce' have especially strong performance in intermediate skills products such as motor vehicles, machine tools, and power-generating equipment (Crouch *et al.*, 1999: 106).

By contrast, historically the United States and the United Kingdom provided a much smaller proportion of their workforce with the opportunity to acquire skilled vocational qualifications. Both the

United Kingdom and the United States have world-class research universities, especially in the basic sciences and strong links with industry. Both countries have an above-average performance in high-skill intensive exports such as software, aerospace, advanced defence equipment and fine chemicals. This has led to "strong performance in some highly skilled sectors", but their overall trade and industrial structure is "bifurcated between high and low-skill activities" (Crouch *et al.*, 1999: 215). It is interesting to note that the export volume of these high-skill products from the United States and United Kingdom is small by comparison with their imports of intermediate-level products. Consequently, both countries run substantial merchandise trade deficits (Crouch *et al.*, 1999: 107).

The above points to the importance of intermediate skills in shaping the capacity for product and process innovation, productivity, quality and, consequently, in determining how and what products and services are produced and the international competitiveness of this output. It is important to note that higher level intermediate workforce skills, whilst important, are but one factor in the innovation system of nations such as Germany and Japan. Many other elements have been identified in these systems such as technology diffusion programmes and even "patient" capital (Streeck and Yamamura, 2001).

2.6 Reasons for increased academic and policy interest in skills and innovation

Over the last four decades there has been intensified interest in the subject of skills and innovation. The reasons for this increased interest include:

2.6.1 Rising educational attainment

Across developed and developing countries substantial increases have occurred in both educational attainment of the workforce and share of the workforce employed in higher skilled occupations, typically identified as managerial, professional and associate professional occupations (Kim, 2002: 91). This is conventionally attributed to changes in production technology and work organisation methods which, it is claimed, require higher level skills.

2.6.2 Skill shortages

As a consequence of the rising demand for higher level skills many nations experience skill shortages across a broad range of occupations that typically require university or other post-school qualifications for entry. These shortages are argued to reflect 'supply side' inadequacies within educational institutions given their failure to deliver a sufficient quantity and quality of trained persons. These training institutions are also claimed to under-perform in the delivery of 'generic' or 'employability' skills (Muelemeester and Rochat, 2004). Just as rising educational attainment is claimed to be a direct function of new technologies, conversely, skill shortages are argued to restrain the capacity of economies to innovate (Hayward and James, 2004: 2). (The topic of generic skills is dealt with in more detail below).

2.6.3 Demographic change

Declining population levels and aging demography in some developed economies are argued to exacerbate skills shortages and potentially threaten long-run economic growth.

2.6.4 Globalisation and competition

Global competition is intensifying, especially from developing countries that combine the benefits of low unit labour costs with modern capital equipment and rapid increases in educational attainment. National governments in developed economies and transnational agencies, such as the OECD and European Union, recommend higher workforce skills and associated investment in product, process and organisational innovation as a strategic response to this rising competition (HM Treasury, 2004; Muelemeester and Rochat, 2004; OECD, 2007).

2.6.5 Changing work organisation

Intensifying global competition has also led to the diffusion of more productive work organisation methods. These methods are based on principles such as team-work, devolution of management responsibility and high levels of workforce engagement in continuous product and process improvement. This is argued to require not only mastery of occupationally specific competencies but also an understanding of the theoretical principles and knowledge that underpin routine tasks. This broader understanding is necessary to engage in creative problem solving and experimentation (Keep and Payne 2004: 55). Other skills include literacy and numeracy; facility with computers; verbal communication skills and capacity to engage with external suppliers or customers.

2.6.6 Technological convergence

ICT has also led to the convergence and integration of technologies in production systems requiring both higher level technical skills and multiskilling (Kim, 2002: 92; Tether *et al.*, 2005; Taylor, 2006).

2.6.7 Changing industrial structure

Rapid changes in the industrial structure, with consequent rapid shifts in the demand for different types and levels of skills, has increased incentives for individuals to acquire adaptable and 'transferable' workforce skills (Kim, 2002: 92; HM Treasury, 2004).

2.6.8 Consumer demand

Changing patterns of consumer demand, especially the move towards more design intensive, higher quality and customised products and services, is argued to require higher level skills in the production and delivery of these commodities.

2.6.9 Importance of low technology industries

Notwithstanding the above, and despite the past academic and public policy focus on fundamental scientific inquiry as the driver of technological change, it is increasingly recognised that most workers across the OECD are employed in 'low technology' and low innovation-intensive industries (Hirsch-Kreinsen, 2008: 20). The importance of incremental innovation in these industries and the particular workforce skills required for this form of innovation has also been increasingly recognised. Moreover, given the large share of GDP comprised by 'low-tech' industries and strong inter-industry linkages with other sectors it is argued that even modest gains in efficiency and innovation in low-tech industries contributes disproportionately to aggregate increases in productivity and national innovation effort. Low-tech industries also perform the critical role of a major user of the products and services of high-tech industries (Hauknes and Knell, 2009). The output of low-tech industries are often 'commodities', like steel, cement, food processing or retail services, but their production processes can employ advanced IT or automated systems which are sourced from 'high-tech' industries.

2.6.10 Contribution of human capital

Academic studies, especially from a neoclassical orientation, have been influential in quantifying the contribution of 'human capital' to economic growth. These studies have demonstrated firstly, the strong positive association for individuals between educational attainment and earnings. This is interpreted as a direct result of the higher productivity of more educated labour and strong complementarity between human and physical capital. Secondly, growth accounting techniques have established the large contribution of investment in human capital and expansion of knowledge in explaining the enormous differences in per capita income across developed and developing countries (Romer, 1994).

2.6.11 Neoliberal policy

The rise of neoliberal economic policies across most developed economies over the last 40 years has also been argued to have focussed policy attention on skills and innovation. Previous activist industry policy, which sought to shape the industrial structure and performance of firms through means such as export incentives, subsidised loans and government procurement, has been mostly rejected as a legitimate objective and instrument of economic policy. As a consequence, it has been argued that, especially in Anglophone countries, “intervening on the supply-side through education and training has become almost the only socially and politically acceptable way for government policy to be used to raise the economic competiveness of organisations” (Fernandez and Hayward, 2004: 79).

3. APPROACHES TO THE STUDY OF SKILLS AND INNOVATION

As noted in the introduction, the topic of skills and innovation has been studied from many different academic disciplines each with distinctive methods and assumptions. There is not the space to consider all of these multiple perspectives, therefore, the focus of this chapter is on summarising the approaches and findings of what are arguably the three dominant and distinctive schools of thought on the topic. These are firstly, human capital theory and a more recent variation on this theory that argues major changes in the labour market of developed economies, notably the rising demand for higher skills and qualifications, is a response to 'skill biased technical change'. Secondly, comparative international studies find that the acquisition of high-level intermediate skills by a large proportion of a workforce depends on a set of inter-locking institutional arrangements governing not just training but also industrial relations, industry policy, education and welfare. Moreover, this literature provides strong evidence to demonstrate how higher-level workforce skills directly affect the capacity of individuals and firms to engage in product and process innovation. Finally, it has been suggested that for a range of reasons, such as increased global competition, employers are increasingly adopting organisational innovations which require employees to attain higher level technical skills and a broader range of skills in order to implement 'high performance work systems'. This chapter also summarises the key criticism of these three approaches.

3.1 Neoclassical human capital and skill biased technical change

Neoclassical growth accounting techniques suggest that the expansion of total output is due to an increase in the quantity of inputs, capital and labour, and improvement in the quality of these inputs over time.[22] Improvements in the quality of inputs are the result of technical change embodied in improved capital goods and intermediate inputs and improvements in the quality of labour as a result of increased investment in education. There are two mechanisms whereby improvements in the quality of labour improve the productivity of labour. Firstly, 'human capital' is regarded as analogous to physical capital, in that increased 'investment' in labour, especially through education and training, improves the productivity of labour. In other words, 'human capital is one of the prime determinants of labour productivity' (HM Treasury, 2004: 8). Secondly, improving the quality of labour through education and training increases the complementarity between labour and capital. Higher-quality labour raises the productivity of capital, stimulates further capital investment, and hence raises the demand for skilled labour.

The primary evidence for the link between human capital and productivity are statistical studies showing a strong correlation between increments in human capital, which is proxied by either years of schooling or level of qualification (such as high school diploma, bachelor or post-graduate degree) and hourly earnings. In addition, cross-country comparisons show a strong relation, firstly between workforce educational attainment and per capita GDP and secondly, educational attainment and capital per worker.

3.1.1 Skill biased technical change

Over recent decades much research has been devoted to explaining what appear to be a number of paradoxes in skills and innovation. First, in Anglo-Saxon countries in particular, there has been a trend for

[22] For brevity this section combines the views of the standard neoclassical approach and augmented neoclassical 'new growth theory'. The latter seeks to 'endogenise' technical change.

the real wages of the more highly educated to rise relative to persons with lower educational attainment. That is to say, the returns to additional years of education increased. This is despite the fact that the rate of growth of the university educated workforce has grown at a much faster rate than for the workforce as a whole (Lafer, 2002: 45). Expressed another way, what accounts for the capacity of the economy to absorb such a rapidly rising quantity of inputs to production. Standard neoclassical theory would suggest that the rapid increase in supply of more educated labour should have constrained real wages and/or that diminishing returns to a factor, that is human capital, should have set in, again resulting in a reduction in real wages for the more educated. The second principal paradox in the labour markets of developed economies is that, despite an increase in the demand for skills, there has been a decline in the share of 'middle skill' occupations in total employment and a rise in the share of lower skilled occupations (Goos and Manning 2003).[23] The latter include occupations such as cleaners, drivers, department store sales people, fast food operatives and other personal service workers. Technological change causing growth of employment at the top and bottom of the labour market and decline in the middle is also a factor in growing income inequality in countries such as the U.S. (Johnson 1997).

The first apparent paradox can been resolved if it can be shown that there has been a large and sustained increase in the relative demand for more highly skilled labour. The factor that is behind this increase is 'skilled biased technical change (SBTC)'- a pattern of technical change over several decades which "has favoured the wage and employment prospects of relatively skilled workers, while simultaneously damaging the wages and employment of the less skilled" (Machin and Van Reenan, 1998: 1215). SBTC results from 'a significant complementarity of human capital with new technology' (Machin and Van Reenan 1998: 1216). Over the years studies of SBTC have employed a number of measures of increase in technical change. These include for example, inputs to technological change, such as change in R&D intensity of firms and industries (Machin and Van Reenan, 1998; Colecchia and Papaconstantinou, 1996); investment in computers and software (Krueger, 1993); investment in machinery and equipment (de Laine, Laplagne and Stone, 2000) or output measures such as number of patents generated (Kim, 2002: 93). Measures of 'upskilling' include increases in the proportion of persons with post-school qualifications and/or increase in the proportion of persons in skilled white collar jobs (professional, managerial, and associate professional), and skilled blue collar jobs (technicians and tradespersons).

In many of the early studies of SBTC the precise mechanism linking a rise in a proxy for technical change, say R&D, with an increased demand for skilled workers was not well specified, and the analysis typically relied on the strength of a statistical association between the two variables. Later studies, especially those focussing on investment in computers, or ICT more broadly, provide a plausible chain of causation from technical change to a change in the skill and occupational composition of the workforce (Autor, Levy and Murnane, 2003; Goldin and Katz, 2007). The basic argument is that many 'routine' tasks, whether manual or service activities, can be reduced to a set of programmable rules and the outcome of these activities, if not the exact task itself, can be replicated by a computer or computer controlled

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23 Other paradoxes are also to be found in the literature. Why have the returns to education increased given the accelerating pace of technical change and the inherent obsolescence of formal qualifications implied by this? One solution, described earlier, is that higher levels of education create a general ability to adapt to technical change. In addition, if the returns to education are so obvious why has not the rate of investment by firms and individuals in education and training been even higher? The standard Human Capital explanation is that:

i. Externalities prevent firms from capturing all the benefits of investment in training and this leads to firms under-investing in training (for example, workers finding employment with another employer after having received training);
ii. Inadequate information as employees and employers cannot judge correctly the benefits of training; and
iii. Credit constraints, in particular, for lower-paid individuals or for small organisations.

machine. By contrast higher-level skills, be they manual or cognitive are ‘non-routine’ in that they are mostly non-repetitive and cannot be reduced to a set of unambiguous rules. Some of these skills embody ‘tacit’ knowledge, which even the user of such knowledge cannot express. In Karl Polanyi’s famous aphorism “we know more than we can say”. In such cases decision-making cannot be reduced to a computable algorithm but relies on experience and judgement. ‘The capability of computers to substitute for workers in carrying out cognitive tasks is limited…Tasks demanding flexibility, creativity, generalized problem-solving and complex communications – what we call non-routine cognitive tasks – do not (yet) lend themselves to computerization’ (Autor, Levy and Murnane, 2003: 5).

The effect of such technological change also provides a plausible explanation for declining employment of middle skill occupations and increase in lower skilled occupations.

> *“The routine tasks in which technology can substitute for human labor include jobs like craft manual jobs and book-keeping, jobs that require precision and, hence, were never the least-skilled jobs in the labor market. The non-routine tasks which are complementary to technology include ‘skilled’ professional and managerial occupations jobs but also many of the most ‘unskilled’ jobs such as shelf filling that rely on handeye coordination that virtually all humans find easy but machines find enormously difficult...the impact of technology will be to lead to rising relative demand in well-paid skilled jobs (that typically require non-routine cognitive skills) and in low-paid least skilled jobs (that typically require non-routine manual skills) and falling relative demand in the ‘middling’ jobs that have typically required routine manual and cognitive skills – a process we call job polarization” (Goos and Manning 2003: 1-2).*

Non-routine high level and low level skills are complementary to ICT investment whereas ICT substitutes for middle level skills.

Job polarization is reinforced by two other effects of technological change on routine jobs. These are the ‘offshoring’ of routine middle-skill jobs, such as manufacturing, clerical and administrative jobs from developed to developing countries and then importing these outputs to developed economies (Goldin and Katz, 2007; Goos, Manning and Salomons, 2010). Second, a decline in the real price of routine low skill goods and services, even assuming a modest price elasticity of demand for these goods and services, increases their demand and output. This decline in the relative price of lower-skill routine goods and services is due to the productivity enhancing effect of ICT and use of lower priced ‘offshored’ inputs. “[R]outinization will result in larger falls in prices in industries that historically used a lot of routine labor, and this will tend to benefit all labor that is used in these industries” (Goos, Manning and Salomons, 2010: 30).

In summary it is clear from the above that human capital theory has provided the essential service of focussing attention on the critical role of education, training and work experience in raising productivity and capacity for technical change. Over recent decades a more nuanced understanding of the effect of technology on the labour market and demand for skills has developed based on the evolving concept of skill biased technological change. This has proven a persuasive and influential explanation of key developments in the demand for skills in advanced economies. These developments include a rising proportion of the workforce with higher levels of educational attainment, polarisation in the demand for skills and occupational competition of the workforce and, in some countries, growing income inequality.

3.1.2 Criticisms of skill biased technical change

Do technology and skill differentials drive wage inequality?

More recent work explaining key labour market structural shifts, such as rising income inequality from the 1980s, have identified other factors that are unrelated to technical change and account for the much of the structural shift that SBTC is intended to explain. In the United States Goldin and Katz (2007: 153-154) found:

> *"That a sharp slowdown in skill supply growth rather than a persistent acceleration in demand growth has been the driving force behind the large rise in the college wage premium from 1980 to 2005. The relative supply of college workers increased by 3.89% per annum from 1960 to 1980 and the college wage premium did not rise. But college relative supply increased at just 2.26% per annum from 1980 to 2005 and the college wage premium increased by 0.90% per annum. Relative demand growth was similar on average from 1960 to 1980 as well as from 1980 to 2005 when a deceleration in relative supply growth occurred that more than fully explains the post-1980 rise in the college wage premium…[income inequality increased from 1980] because educational growth has been sluggish, not because the rate of skill-biased technological change has accelerated".*

In turn, the slowdown in the relative supply of college educated persons in the working population from 1980 was caused primarily by a slowdown in the growth in the educational attainment of persons born in the United States after the 1950s (Goldin and Katz, 2007: 3).

Another line of criticism of the SBTC thesis challenges the idea that the difference in education level between college and non-college educated persons in the United States is the principal factor in rising income inequality. This criticism is based on the idea of labour segmentation, where the factors governing wage growth for that part of the labour market not requiring college education for entry, which represents the majority of workers in the US, are different from that determining wage growth for managers, professional and associate professionals. This argument suggests that a range of institutional factors and structural changes in the US economy unrelated to SBTC largely explain rising income inequality over the last three decades. These factors include a large reduction in union density in the US workforce, with the share of unionised workers declining from 25% in 1978 to 14% in 2000. Unionised workplaces enjoy a large wage premium such that their weekly earnings, compared to non-unionised workplaces, are 21% higher and total compensation (*e.g.* health insurance and pensions) is 28% higher. These earnings differences hold after controlling for 'occupation, industry, work schedule, geographic region and company size' (Lafer, 2002: 78-79). In addition, the failure to adjust legislated minimum wages adversely affected one segment of the US labour force, that is, the lower skilled. From 1968 to 2001 there was a real reduction of 31% in the earnings of those on the legislated minimum wage (Lafer, 2002: 81). The rapid growth of what is termed 'non-standard' employment, casual, part-time and 'disguised' self-employment is also associated with a deterioration in earnings growth and working conditions (Lafer, 2002: 82).

A similar conclusion was drawn by Card and DiNardo (2002:776) who found a range of institutional factors in the U.S. such as 'trends in the minimum wage...declining unionization' and the 'reallocation of labor induced by the 1982 recession' to be the prime causes of 'the rise in overall wage inequality in the early 1980s. Overall, the evidence linking rising wage inequality to SBTC is surprisingly weak'.

Computer usage and wage differentials

There is strong plausibility to the argument that computer use, and ICT broadly conceived, is a major cause of change in occupational structure in advanced economies. However, the extent to which use of computers by individuals is a cause of income inequality is much more contentious. Krueger (1993) found that over the 1980s and early 1990s workers in the United States who use computers on the job earned 15 to 20% more than nonusers after controlling for standard worker attributes. DiNardo and Pischke, (1997) reproduced the study using German workforce data and found a similar wage differential for computer use. However, the same differential also applied to use of other office tools such as pencils, calculators and even sitting in a chair. The interpretation of this unusual result is that firstly, computer use is not random but occupationally specific and that there is some degree of 'selection' in who is employed to use computers, and secondly, use of computers, and indeed office equipment, may be a proxy for some other, unspecified skill, whose return has increased during the period (DiNardo and Pischke 1997: 301-302).

Education or signalling

A related criticism made of the Human Capital argument is that the strong positive relation between higher levels of education and higher levels of earnings is caused by increments in education or learning that increases labour productivity. From a neoclassical perspective investment in education represents the acquisition of 'intangible' capital analogous to physical capital investment. However, participation in higher levels of education is not random; it is associated with a range of personal attributes such as innate ability, perseverance, discipline, conformity to social norms, accepting authority and even better health (Weiss, 1995). People with these 'unobserved characteristics' invest in higher levels of education to 'signal' to prospective employers they possess these qualities. Higher levels of education thus serve as a proxy for these desirable attributes and employers use qualifications to 'sort' prospective employees.

Separating the effects of education from unobserved characteristics has generated an enormous and highly inventive research endeavour. (Some studies even make use of identical twins to 'control' for innate ability). Various studies have examined earnings differences between completers and non-completers of high school, controlling for the effect of grades achieved and type of courses selected by students, such as science and maths subjects compared to languages. These studies find 'that courses, test scores, and measurable learning in secondary school can explain at most one quarter of the increased earnings associated with completion of high school, and probably substantially less' (Weiss, 1995: 140). These studies suggest that a major factor in the earning differentials between completers and non-completers of high school is not so much measured effort directed to learning, but personal attributes. A key factor explaining wage differentials between non-completers and completers of high school is a higher rate of quitting jobs amongst non-completers. A higher quit rate is associated with lower earnings resulting from periods of unemployment, lower scope for promotion within a firm and lower productivity given the positive association between job tenure and productivity.

Wolf (2004) has correctly objected that the signalling versus human capital debate is too often presented as an either/or debate; that education has no effect and labour market outcomes are all the result of individual innate differences or that individuals are a *tabula rasa* with labour market outcomes fully determined by educational differences. The more plausible position is that 'education imparts new and valuable skills and knowledge...it is also, second, correlated with underlying ability, and used, with some justification, by employers as a proxy for this. Third...education provides credentials...[which are] important in the labour market in rationing and controlling access to jobs' Wolf (2004: 319).

Wage dispersion and over-education

Another problem for the simple Human Capital story is that variation in hourly earnings *within* groups having the same level of education is greater than the average variation *between* groups having different educational qualifications. That is to say, the strong association between increments in educational attainment and average earnings hides enormous variation (Lafer 2002). From a neoclassical perspective this enormous variation in earnings within the same level of education is attributed to a range of factors such as differences in occupation, innate differences within people having the same educational attainment and investment by individuals in further job-specific training (Ingram and Neumann, 2006; Autor and Katz, 2007).

In addition it is difficult to square the claim of a generalised rise in the demand for skills with studies that suggest credentialism and over-qualification are widespread in developed economies (Brynin 2002; Wolf 2004; Green and Zhu, 2010). 'The feeling of overqualification is quite widespread across Europe... Overqualification is a puzzle for human capital theory, and it does not fit well with skill biased technical change' (OECD 2010: 109). These results have given rise to concern over the potential waste associated with over-education.

The effects of 'over-education' are, however, complex. Assessing the returns to qualifications produces ambiguous results depending on the specification of the test. Examining the earnings of people with the same qualifications but in different occupations, after controlling for all other factors such as age, experience, industry, hours worked, location etc., shows quite marked negative returns to education for jobs requiring a lower level of educational attainment for entry. Such a result is to be expected as it confirms the common sense observation that wage levels are primarily determined by the type of occupation not the educational qualification of the job holder. In contrast, comparing the earnings of persons in the same occupation with differing levels of qualification reveals a positive return to over-education (Groot and van den Brink, 2000; Fernandez and Hayward, 2004). One interpretation of the latter result is that higher levels of education contribute to the achievement of higher productivity regardless of the occupation. (But, as noted above, separating increments in education from innate ability or other desirable characteristics is methodologically difficult).

An insight into the effect on jobs and workplaces of employing persons who are over-qualified is provided by a UK study which examined the reasons for and impact of growth of employment of university educated young people in a range of service industries, in occupations that traditionally did not require this level of education for entry (Mason, 2002). The industries studied were retail, telecommunications and transport and the occupations identified as not requiring university qualifications for entry were those below professional, managerial and associate professional level and included jobs such as clerical, sales, and customer service. The time period covered by the study was the 1980s and 1990s, which coincided with a large rise in the supply of university graduates due to an earlier expansion of higher education. The substitution of graduates for non-graduates was attributed by employers in these industries to an increased supply of graduates applying for non-graduate jobs and rising employer demand for skills and knowledge. Graduates were taken on:

> *"In increasing numbers to fill positions requiring high levels of analytical ability, generic skills and, in many cases, technical knowledge. In part this reflects increased competitive pressures to improve efficiency and responsiveness to changing markets along with the spread of project-working and other changes in work organisation which benefit from high levels of information processing, communication and other generic skills" (Mason, 2002: 428).*

This study is important as it shows, firstly, how increased flows of skills can change the content of tasks performed and secondly, it raises questions about the validity of using standard occupational classifications to assess both the skill level of occupations and the degree of over-education.[24]

[24] Despite the large increase in both educational attainment of the workforce and proportion of jobs requiring these qualifications in advanced economies it must be acknowledged that across developed countries "large numbers of jobs remain mind-numbingly mundane, low skilled, low waged and insecure, and require little training to perform them" (Keep and Payne, (2004: 64).

A different perspective on 'over-education' is suggested by some writers who note that in previous generations a much larger proportion of workers in professional, semi-professional occupations commenced their jobs without first obtaining formal qualifications or training. People entered these jobs and underwent a form of apprenticeship combining work and off-the-job training. This was common for example in law, accounting, pharmacy and surveying. One of the consequences of the shift in recruitment practices to require professional qualifications prior to job entry is a decline in occupational mobility, or people moving from lower to more skilled occupations after they have commenced their working life (Hudson, 2002: 78-79).[25] Reduced occupational mobility increases the incentive to acquire formal and higher-level qualifications as barriers are raised to the traditional route of 'working your way up'. This suggests a mechanism whereby investment in education is cumulative. As employers increasingly expect new entrants to possess qualifications this increases the incentive for school leavers to enter education rather than the labour market to obtain entry qualifications and this, in turn, leads employers to remove job openings for the unqualified in favour of qualified new entrants.

3.2 Institutions and national differences in skill formation regimes

The central role of incremental innovation, or the use and adaptation of existing knowledge and techniques to improve the stock of products, services and processes, would strongly suggest that VET occupations, especially at trade and technician level, *should* be key agents in this process. However, the studies on matched plants and trade performance summarised in chapter 2 point to a great diversity across advanced economies in the skill level and role of direct production workers in national innovation systems. The purpose of this section is to very briefly describe the factors that influence firstly, differences across advanced economies in the proportion of the workforce with higher level VET qualifications and skills and, secondly, the extent of the involvement of the VET workforce in innovation. [26]

The literature on the institutional foundations of national skill formation regimes identifies three broad types of intermediate skills formation systems; 'occupational', 'internal' and 'flexible'. In summary, the literature suggests that national intermediate training systems are the product of a complex historical process which create 'institutional complementarities'. These are a set of self-reinforcing institutions, which create economic incentives and legal and social obligations on workers and firms to invest in particular forms of workforce training and for firms to adjust their production systems and products to these particular types and level of skill (Hall and Soskice, 2001).[27] Each of these systems has distinct effects on the type and level of VET skills; participation of direct production workers in innovation and the type of innovation conducted within these systems.

3.2.1 Occupational labour market

The institutional foundation of the occupational labour market, of which the German apprenticeship system is regarded as the archetype, is commonly interpreted as a means of redressing 'market failure' in the delivery of employer funded transferable training. Transferable skills are those for which there is demand in the external labour market. Employers are unwilling to invest in providing these skills to employees because workers who receive this training can leave to work for another firm before the employer has recouped the cost of training in terms of higher productivity and output. Thus firms that do

25 One can think of many barriers to people gaining formal qualifications, such as those from a university after they have been in the workforce for several years. Such people may have family responsibilities and mortgages which preclude them leaving work for education.

26 VET qualifications are generally regarded as International Standard Classification of Education 4A, 4B and 5B.

27 There is not the space to discuss the historical origins of these three systems but an excellent account is provided in Thelen 2004.

not train, but instead poach skilled workers, gain a cost advantage over firms that do train. From a conventional neoclassical perspective the apprenticeship system is viewed as a response to this dilemma as the costs of training are shared by the apprentice accepting a lower wage during their training than they can obtain in the external labour market, in return for the employer investing in imparting transferable skills (Becker 1994). However, without a complex set of institutional supports such a system is likely to prove unstable, as evidenced by the long-run decline of apprenticeship systems in many other countries, such as the US and UK (Gospel, 1991). This instability arises from:

> *"The difficulty of securing mutually credible commitments from both parties to a training contract…Unless some mechanism is found to force firms to train well and to prevent them from exploiting apprentices, at the same time forcing apprentices to stay long enough for a company to recoup its investment, apprenticeship training is likely to deteriorate into cheap unskilled labour" (Thelen, 2004: 18).*

Indeed, a system in which transferable skills are certified and their quality assured is paradoxically likely to promote poaching. This is because certification overcomes information asymmetries regarding the quality of skilled labour between firms that train and those that do not (Thelen, 2004: 19-20).

The following lists some of the institutional supports that are the foundation of the occupational labour market. These institutions impose obligations and provide incentives for employers to train and for young people to invest their time in acquiring these skills:

- Underpinning the German vocational system is a high average level of educational attainment in schools. This ensures a high proportion of the workforce has the literacy and numeracy skills to complete higher level technical training. Around 70% of young people undertake an apprenticeship with a completion rate of around 75-80% (Ryan and Unwin, 2001). The content of apprenticeship training is not just narrowly focussed on vocational training but includes general education in terms of literacy, numeracy, civics and in some fields even other languages.

- Tripartite co-ordination between employer associations, unions and the state in order to strike the right balance between employers and employees in terms of the scope and duration of training. Employers typically want firm-specific short duration training, whereas employees want skills that are recognised, transferable and provide a decent wage in the external labour market. Joint agreement over the scope of skills, methods for delivery and crucially for assessing the quality of skills ensures that qualifications are widely recognised across the economy. These agreements also 'hinder firms from exploiting apprentices because firms whose trainees regularly fail standardized certification exams are likely to lose their license to train (and with it the contribution of low-wage apprentices to production). A system of skill certification also reduces the incentive for apprentices to leave early because trainees have to say long enough to receive their certificate, which then becomes a widely recognised ticket to better jobs' (Thelen, 2004: 18 -19).

- The state is also crucial in creating a statutory basis for apprenticeship; typically in legislation that governs the contract of employment and training between the apprentice and employer. This contract specifies the rights and duties of both parties. State financial support of quality training infrastructure is essential, along with 'licence to practice' laws requiring those running a trade-based business such as electrical contracting, building, baking and bricklaying etc. to have completed trade qualifications and to undergo additional business related training. The strength of employer associations is underpinned by the fact that in Germany employers are required to be members of local chambers of commerce and there are high rates of unionisation.

- Industry level industrial relations bargaining ensure more or less uniform wages and conditions for qualified trades and technicians in the same occupation across firms. Such 'sectoral agreements on wages and skills…prevents employers from poaching employees trained by other firms with enhanced pay offers' (Green and Sakamoto, 2001: 71). The centralised wage setting system also provides well defined occupational career paths and wage increments based on the acquisition of qualifications.

- The pursuit of active state industry policy to diffuse the latest production technology and workforce organisation methods is critical in sustaining industries that intensively use higher level workforce skills. This support of German manufacturing industry in particular generates a virtuous circle of demand for and supply of quality intermediate skills.

- Generous welfare provisions in the event of unemployment and constraints on redundancies through legislation and co-determination at a firm level provide workers with incentives to acquire occupationally specific skills. It has been argued that less regulated labour markets, especially those with minimal employment protection and minimal unemployment insurance, create incentives for workers to invest in additional years of schooling or university education in order to acquire general skills. These are skills, such as high proficiency in literacy, numeracy, capacity to learn and broad management abilities that are applicable across a range of occupations and industries. General skills reduce the chance of unemployment in the event of redundancy (Estevez-Abe, Iversen and Soskice, 2001). [28]

The system of training within an occupational labour market encourages product and process innovation through the following mechanisms:

- First, high wages for tradespersons and technicians have the effect of 'forcing German employers to maximise the productivity return on skills' and of encouraging labour displacing capital investment (Green and Sakamoto, 2001: 70). Conversely, high wages 'have the effect of deterring company strategies of price competition through low pay and low skills labour' (Green and Sakamoto, 2001: 71).

- Second, a strong commitment to training minimises skill shortages. In addition, widely recognised and accepted qualifications facilitate geographic and inter-industry labour mobility in the event of a downturn.

- Third, the breadth and depth of practical and theoretical skills in apprenticeship training encourages multi-skilling and adaptability which facilitates the introduction of new products and processes. Industry wide unions covering a broad range of occupations facilitate broader skilling compared to narrow occupationally based unions which are far more defensive of occupational demarcations. (As evident in the 'matched plants' studies reviewed earlier).

- Fourth, considerable effort is made to ensure curricula and pedagogy in apprenticeship training is kept up to date. For example federal laws relating to apprenticeship training mandate that training arrangements for new occupations must be in place within 18 months of the initial decision to create an apprenticeship. Apprenticeship training curricula also operates as a form of technology diffusion as it alerts firms to newer technologies and work practices.

[28] It will be recalled that one of the benefits of further education is the capacity to adjust to technical and economic change.

- Fifth, labour market regulations discouraging non-standard forms of employment and sackings results in average years of job tenure rates that are around one third longer than in the UK and three quarters more than in the US (Auer, Berg and Coulibaly, 2005). This higher level of employment security reduces worker resistance to the introduction of new technologies that may otherwise be seen as job-threatening. It also lowers unwillingness to pass knowledge onto co-workers by reducing the fear of losing one's job once this 'personal monopoly of knowledge' is transferred to others.[29] Job stability increases workers' willingness to acquire occupationally specific skills and also promotes in-depth understanding of a firm's particular products/services and processes amongst workers.[30]

- Sixth, a skilled intermediate workforce promotes the transfer of knowledge within a firm from engineering and scientific staff to the direct production workforce and vice versa. Related to this point, the existence of a certified high level of intermediate skills across SMEs and large firms facilitates the transfer of knowledge between more technically advanced larger firms and their smaller suppliers and customers (Green and Sakamoto, 2001: 70).

- Seventh, related to this last point there is a cumulative interaction between the existence of a large skilled direct workforce and the extensive publicly supported technology diffusion institutions such as Fraunhofer, Max Planck and Steinbeis Foundations as the former can utilise the advanced technologies promoted by these institutions.

The occupational labour market model produces vocational skills characterised by 'deep competencies within established technologies' (Estevez-Abe *et al.*, 2001: 174). Such competencies are particularly 'suited to incremental innovation and problem-solving but are inappropriate to a world where competition is dependent on rapid changes in basic innovation' (Lauder, 2001: 170). This finding is confirmed by the earlier balance of trade data which shows that Germany is especially competitive in middle technology industries that intensively use intermediate skills.

The above description of the German model represents a simplified 'ideal type'; in reality the stability of the model is under threat from a number of sources. The strong occupational identity of tradespersons does create demarcation problems; it limits willingness to participate in team based learning and activities and changes in work organisation within firms have to proceed through time consuming negotiations. Despite being broadly skilled there remain strongly defended divisions, such as those between electrical and mechanical tradespersons (Herrigel and Sabel, 1999). Employers are also less willing to bear the costs of apprenticeship training due to intensifying price and quality competition from low cost producers (Culpepper 1999). Nevertheless, despite a number of challenges the German system of intermediate skills formation and its institutional foundations remains a core element in the German innovation system.

3.2.2 Internal labour market

The archetypal model of the internal labour market (ILM) is the large Japanese corporation. The production workforce is divided into core permanent and peripheral components. The latter comprises contract and casual workers engaged in routine activities whose level of employment is adjusted to fluctuations in output. Permanent production workers are generally recruited directly from school after

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29 Prescott (1998) gives particular priority to the capacity of sectional interests in some countries to resist technical change as a major factor explaining long-run international differences in per capita income.

30 A quantitative study of 14 European nations, Japan, and the US on the relationship between productivity growth and job tenure over the period 1992 to 2002 found that a one per cent increase in the average rate of tenure would increase productivity by 0.16%. The benefit of job stability reaches a peak at 13.6 years and declines slowly thereafter (Auer *et al.* 2005: 7)

rigorous selection tests. As in Germany a high average level of literacy and numeracy amongst school leavers underpins workforce capacity to undertake higher level vocational training, flexibility to introduce new technologies and active participation in the production process (Green and Sakamoto 2001: 112).

The core permanent workforce receives mostly on the job training designed to meet the particular needs of the firm. These workers are prepared to invest in this firm-specific training in return for employment security and a career path within the firm (Thelen 2004). Training is directed at producing multi-skilled workers through job rotation and a capacity and willingness to engage in group problem-solving. Multi-skilling and a high level of functional flexibility (or low levels of occupational demarcations) are encouraged by the linking of pay to experience and time served with the firm rather than to current production tasks undertaken. Job security significantly reduces resistance to the introduction of potentially job-displacing new technologies. The following highlights some of the key differences between the outcomes of training within the German occupational labour market and the Japanese internal labour markets models.

> *"Rather than relying on groups of differently skilled workers with general knowledge of their speciality to solve problems that arise in production, the Japanese attempt to respond to problems that arise in production by creating groups appropriate to the task. There are no fixed occupational identities in the Japanese production process. Unlike German workers, who come into the production process only after a long apprenticeship within a particular Beruf [occupation] Japanese workers enter the factory with relatively little knowledge of specific kinds of work. They enter groups within the factory that are actively engaged in collectively solving problems that they encounter in fulfilling orders in production. Apprenticeship is replaced by participation in collective problem-solving on the shop floor. Identities at work associated with craft skill are replaced by identities at work associated with the capacity to contribute to the competitiveness of the company" (Herrigel and Sabel, 1999: 89).*

Another essential feature of the Japanese VET skill formation system is the high degree of co-operation, especially in technology transfer, including skills training, between larger firms and their sub-contractors and across sub-contractors (Fujimoto, 2000).

A disadvantage of the ILM model of high labour productivity is that in Japan it is restricted to a few industries, notably the manufacturing sector. This contrasts with Germany where apprenticeship training occurs in a broad range of industries, including service industries, and underpins high productivity and quality across many sectors of the economy (Ryan and Unwin, 2001). In addition, the foundations of the ILM model, especially the commitment to retain core employees, are being undermined by a squeeze on company profits due to an extended period of low domestic demand from the early 1990s. Traditional overseas markets for Japanese exports are also subject to rising competition from low cost Asian nations which, in turn, has prompted the re-location of Japanese manufacturing to these same low-cost nations. Younger workers are also less attached to traditional career paths. In response to these changes large corporations have significantly increased the share of their workforce in non-standard forms of employment- or increased their peripheral workforce and reduced the core (Gaston and Kishi, 2005). As argued in the next section non-standard forms of employment are generally not conducive to workforce participation in innovation at a firm level.

3.2.3 Flexible labour market

The United Kingdom and United States are regarded as the principal examples of this labour market and skill formation model. The flexible labour market is typified by low levels of labour market regulation and unionisation; high rates of labour turnover outside of the unionised sector due to the ease of hiring and firing; enterprise based bargaining; and a labour market split between a 'core' permanent workforce and a large 'peripheral' workforce employed on non-standard conditions such as casuals, contractors and labour hire. The large peripheral workforce reflects the priority given to 'numerical' flexibility in terms of closely matching labour utilisation to fluctuations in demand. The extent of occupational licensing for intermediate skills is more limited in the United Kingdom and United States and this is one factor that reduces 'the incentives of employers and employees to invest in skills' (Green and Sakamoto, 2001: 127).

The flexible skill formation system is also typified by a polarisation of skills, with a large proportion of university educated graduates, a large proportion of the workforce with no or minimal post-school qualifications and a comparatively small share of persons with high level intermediate qualifications (Green and Sakamoto 2001: 126). This polarised distribution of:

> *"Skills more or less matches the needs of different industries according to their dominant competitive strategies. The abundant skilled elites with their scientific, creative and entrepreneurial talents meet the primary demands of high skills and knowledge based industries… At the other end of the scale in terms of competition strategies are those industries which compete to a large extent on price and flexibility, benefiting from low levels of labour market regulation and an abundance of relatively cheap, flexible labour" (Green and Sakamoto, 2001: 144).*

Both the UK and US have been effective at innovation based on high level elite skills in science and technology derived from world class universities. A variety of indicators, such as R&D intensity, trade performance and patenting activity attest to the strength of this high level science base in industries such as pharmaceuticals, chemicals, electronics, software, defence and aerospace. High level skills also underpin international competitiveness in financial services and creative industries like advertising, publishing, design, entertainment and management consulting (Tether *et al.*, 2005: 70). Importantly, however, industries that intensively use elite skills employ only a minority of the workforce and the exports of such goods and services is insufficient to offset the much larger volume of imports that intensively use intermediate and low skills.

The absence of labour market regulations on hiring and firing and high levels of job mobility, including amongst the scientific, engineering and managerial elites, is well suited to industries such as software, finance and biotechnology that are reliant on 'rapid product innovation strategies' and a 'high responsiveness to new business opportunities' (Estevez-Abe *et al.,* 2001: 174). A high level of labour mobility, especially amongst the technical elites, is also a critical means of technology diffusion in industries in which change in technology and markets is particularly rapid (Finegold, 1999).

Underpinning this skewed skill distribution is 'unequal outcomes of initial education and training' (Green and Sakamoto, 2001: 131). The United Kingdom and the United States have a much higher proportion of their adult population that are functionally illiterate and innumerate, compared, for example to many countries in Europe and Japan (Green and Sakamoto, 2001: 131; Tether *et al.*, 2005: 52-3).[31] This polarisation in outcomes from the general education system is not redressed through the VET system. The US does not have a national system of vocational qualifications and the weak educational attainment of a large proportion of the workforce leads employers to provide 'non-graduates…[with] firm specific types of training' characterised by 'narrow skill sets' (Tether *et al.,* 2005: 58). Individuals can acquire good vocational skills through community colleges, but this often requires them to invest in their own training for up to two years. The UK has, with a few exceptions, a poorly performing VET sector (Gospel 1998; HM Treasury 2004). For example, the level of skill certified under an 'apprenticeship' in the UK is low

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31 In the mid 1990s around 25% of 16-25 year olds in the United States and around 18% of the same group in the United Kingdom were classified to the lowest level of literacy and numeracy based on international standardised tests. This compares with well under 10% in Germany, Sweden, Switzerland, Belgium and the Netherlands. (Tether *et al* 2005: 53).

compared to that in many European countries and Australia (Ryan 2000; King 2001; Toner 2008). The range of skills required for these qualifications is also narrow so that the qualifications system militates against broad based multi-skilling (Clarke and Wall, 2000: 697). In addition, 'competency based' training in the United Kingdom is based on the demonstration of practical skills within a given workplace with little consideration given to imparting or testing theoretical underpinnings. Due to absence of strong union voice in the UK the VET system is dominated by the interests of employers. The result, it has been argued by some, is training which suits the short term interests of individual employers by minimising their costs (through large state subsidies) and maximising the customisation of training to the needs of individual firms (Keep 2006). A multiplicity of private and public training VET providers of greatly varying quality reduces the value and recognition of such qualifications for both workers and employers.

This flexible skill formation model has given rise to the notion of 'low-skill equilibrium' (Finegold and Soskice 1988). The notion of low-skill equilibrium can be viewed as an example from the economics literature of the widely researched and accepted concept of 'technological lock-in' (Arthur 1994). Low-skill equilibrium describes a set of self-reinforcing financial incentives and institutions in which the existence of a large pool of low skill, low productivity workers constrains many firms to produce standardised, low quality goods and services. In the UK vocational training 'provided within firms…has resulted in the formation of narrow, firm-specific skill sets…[that] are not particularly adaptable for engaging with innovation' (Tether *et al.*, 2005: 59). Workers have a reduced incentive to participate in training due to the lack of demand for higher level skills. The low wages of this workforce creates a market for the output of such industries (Keep and Mayhew 2001: 10). Moreover, given the neo-liberal predisposition of governments in the UK and US, there is a general resistance to activist state industry policies aimed at shaping the industrial structure.

The problems created by the flexible labour market model in terms of a comparatively large proportion of the workforce in low productivity, low wage industries and high income inequality have been increasingly recognised in public policy (HM Treasury 2004).[32] The low skill approach persists in some advanced economies because for many firms it continues to be profitable. More broadly, Keep and Mayhew (2001: 14) argue that from the point of view of an individual firm:

> *"Skills are by no means the only, or even the most attractive, route to competitive success, perhaps particularly so in the Anglo-Saxon world. Rather than seeing skills as the key to competitive success, it might be more realistic to view upskilling as simply one model of competitive advantage vying for senior managers' attention in the marketplace of ideas…there are many other competing models available-…mergers and acquisitions, strategic alliances, outsourcing, management by contract, globalisation and economies of scale, and so on".*

32 The following account of the causes and problems for the UK economy of a low-skill equilibrium is from the UK Cabinet Office (2001: 33). 'Though the 'low skills equilibrium' is not a true representation of all sectors of the UK economy, and is, in part, an exaggeration of the actual situation, it provides helpful conceptual insights, including recognition that innovation in products and processes may be discouraged by perceptions of skill shortages. This model also highlights the issue of 'path dependency': once managers adopt a strategy based on a given skill level, it is not easy to adopt a different strategy. Indeed if a previous strategy based on low skills has been successful, management may be reluctant to develop new or enhanced strategies even if a skilled workforce is available. A survey undertaken by the NSTF [National Skills Task Force] found that roughly half the employers surveyed foresaw skills-related problems if they sought to respond to competitive market pressures by developing higher value-added product strategies. Case studies carried out for the NSTF indicated that if companies attempted to move towards higher value-added strategies without complementary changes to human resource strategies, latent skills gaps would be revealed. Once locked into a particular path, it may be difficult to change even if the economy as a whole would benefit from doing so'.

Quantitative studies have found that firms using a flexible labour market model have a lower propensity to train (Draca and Green, 2004). Workers engaged on non-standard employment conditions such as casual, contract or labour hire work are significantly less likely to participate in work related training funded either by the worker or the employer. One UK study found that 'there is a trade-off between expanding the more flexible forms of employment and expanding the proportion of the workforce getting work-related training' (Arulampalam and Booth, 1998: 532). Other studies have found that controlling for a wide range of variables that strongly influence the propensity of firms to innovate, such as industry, employment size, age of the establishment and degree of foreign ownership, firms using the flexible labour market model have a significantly lower propensity to innovate than other firms.[33] The defining features of firms classified to the flexible labour market model in the study were an above-average use of casual and contract employment; high labour turnover and low union membership. Firms which had low levels of such flexible employment practices had a much higher propensity to invest in product and process innovation. The study concluded that 'there is no evidence whatsoever that the sort of 'flexibility' resulting from labour market deregulation leads to a more innovative economy. Far from the creation of such 'flexibility' causing increased innovation, the correlation between the two is found to be negative' (Michie and Sheehan, 2003: 139).[34]

3.2.4. Criticisms of institutional approach

There are a number of important criticisms of the literature on the institutional foundations of national skill formation systems (Allen 2004; Hancke and Rhodes; Thatcher 2007). First individual countries are not uniform but exhibit characteristics that are consistent with the flexible, occupational and ILM labour market models. For example, the Japanese ILM model contains elements, which are more properly classified to the flexible labour market model, especially its use of a large peripheral workforce. Japanese car plants established in the US from the 1970s successfully replicated the home country model such as employment practices, work organisation and patterns of engagement in supplier networks (Florida and Kenney 2000). Australia is conventionally classified to the flexible labour market or neoliberal spectrum but it has a long-established and vibrant apprenticeship system covering many industries such as manufacturing, construction, electrical generation and distribution, restaurants and motor vehicle repair (Toner 2008). As in Germany this system also relies on similar underpinnings such as employer and union co-ordination over the content and duration of training, state support of vocational training colleges and

33 This conflict between the demand for numerical flexibility, or moves to reduce wage costs by narrowing the skill base of labour, and the demand for functional flexibility on the other, was recognised 140 years ago. 'Modern Industry never looks upon and treats the existing form of a process as final. The technical basis of industry is therefore revolutionary, while all earlier modes of production were essentially conservative. By means of machinery, chemical processes and other methods, it is continually causing changes not only in the technical basis of production, but also in the functions of the worker, and in the social combinations of the labour-process…Modern industry, by its very nature, therefore necessitates variation of labour, fluency of function, universal mobility of the worker, on the other hand it reproduces the old division of labour with its ossified particularities' (Marx 1867: 617).

34 This effect is quite strong. Michie and Sheehan's (2003: 134) survey of UK manufacturing found that high labour turnover reduces the propensity of firms to innovate by 26% and high use of fixed term, casual or seasonal employment labour reduces the propensity to innovate by 19%. It could be objected that it is illicit to extrapolate these results from a single industry to the total 'economy'. Moreover, as noted earlier, in the case of the Japanese ILM model high innovation intensity and having a large proportion of workers engaged on casual or contract forms of employment can be compatible. It is generally argued that one of the benefits of the flexible labour market model are lower unemployment rates and higher employment rates (OECD 1994). More recent work by the OECD on the macro-economic effects of labour market flexibility has revealed more nuanced labour market and economic effects. Bassanini and Venn (2007: 22) find that *employment* protection legislation (EPL) lowers labour productivity. Conversely, other forms of regulation such as parental leave and wage compression or narrowing the gap between minimum and median wages are associated with an increase in labour productivity.

legislation governing occupational licensing and industry-wide industrial agreements which define trade occupations in terms of qualifications and tie wage increments to the attainment of qualifications as well as experience. It can be argued that countries do not exhibit uniform institutional characteristics that are fully compatible with neat exclusive categories or an ‘ideal type’ but individual nations, industries and firms display characteristics compatible with multiple institutional models.

This diversity within and across countries points to the fact that there are no objective criteria for allocating a country or industry to a specific institutional model. The inherent subjectivity in allocating a country, industry or firm to a specific model arises from the fact that many of the defining features of the respective models cannot be quantified or are difficult to quantify. Moreover, even with features that can be quantified such as union density or presence and extent of occupational licensing, it is not at all clear what benchmark should be employed to demarcate one model from the next. In addition, it is not clear what features are necessary or sufficient to deem a country, industry or firm as belonging to a particular model.

Second, for policy makers the literature on the institutional foundations of national skill formation systems poses problems. From one point of view the complex array of different inter-locking and reinforcing institutions and social obligations that typify each model could represent a counsel of despair for policy makers attempting to change their national model. For example, introducing significant labour deregulation into a well developed occupational labour market would arguably entail transforming an extraordinarily large range of institutional arrangements. This could involve changes to product market regulation, occupational licensing, the finance system (lowering the savings rate and shifting firms’ reliance on debt to equity to fund investment); the social security system and even possibly widening the distribution of attainment in schooling. It may be objected that this argument is based on a *reductio ad absurdum*, and overstates the difficulties confronting a policy maker intent on change. Nevertheless, it can still be argued that the institutional literature does not provide clear guidance for change because, as noted above, it does not identify necessary and sufficient conditions for a model to operate and therefore provides inadequate guidance to implement change

3.3 High performance work systems

There is increased interest in the literature on skills and innovation on the links between the propensity and intensity of innovation in firms and the different forms of innovation activity that firms and industries can implement and the adoption of specific work organisation patterns (OECD 2010).One particularly well-studied strand in this literature relates to the use of a form of work organisation termed High Performance Work Systems (HPWS). This form of work organisation also requires quite specific workforce skills and, consequently, increased investment in employer funded training. The HPWS literature is important in establishing firstly, a clear link between innovation and a range of particular workforce skills and secondly, that making effective use of workforce skills requires supportive work organisation.

According to Arundel et al (2006: 4) the high performance work system literature deals ‘with the diffusion of Japanese-style organisational practices in the US and Europe and...focuses on the diffusion of specific organisational practices and arrangements that are seen as enhancing the firm’s capacity for making incremental improvements to the efficiency of its work processes and the quality of its products and services’.

3.3.1 Features of HPWS

There is, of course, variation in the implementation of HPWS across industries, firm sizes and to a limited extent across cultures. Despite this a number of features are central to the operation and definition of HPWS and these are summarised below.[35]

1. Rigorous Selection Procedures- Implementing HPWS needs workers with a range of superior attributes such as communication, numeracy, problem solving and team working. Workers are selected for these attributes via screening based on measures such as previous work experience, education and possibly undergoing tests. Selection procedures are also intended to determine the willingness of workers to actually utilise these capacities in the workplace. HPWS demand a more complete utilisation of workers cognitive and behavioural capacities than other work organisation systems.
2. Broad Job Classifications- Functional flexibility in the deployment of workers is achieved by removing, or at least limiting, occupational demarcations and requiring workers to be competent across a broader range of tasks than is conventionally expected. It also requires broad based training.
3. Job Rotation- Workers move through a range of the production tasks within and between work teams. This expands the flexibility of workers and enables team members to better understand the variety of tasks and contribute to continuous improvement. It also reduces repetitive strain or other occupational injuries.
4. Work Teams- production is organised around work teams composed of production workers who are responsible for planning and carrying out production tasks.
5. Worker Initiative- Managerial authority is delegated to shop floor such as design of jobs, routine maintenance and ability to stop production if a fault is detected. Team members are expected to actively pursue continuous product and process improvement to ensure conformity of a product or service with specifications.
6. Flat Management Structure- One consequence of broad job classifications and delegation of authority is relatively few steps in the job hierarchy between team members and senior management.
7. Worker Voice- Aside from decentralised work teams formalised mechanisms for workers collectively negotiating change are an important element in HPWS. Studies have found that the presence of unions is positively associated with innovation. Michie and Sheehan (2003: 138) concluded from their study of UK manufacturing in the 1990s that this is due to ‘trade unions encouraging management to invest in new product design and models, and also more structurally, by cutting off the ‘low road’ option of management getting by in the short term with the existing product range through squeezing wage costs’. Black and Lynch (2004: 3) in their study of workplace practices and innovation in US firms in the 1990s found ‘management practices that encourage workers to think and interact in order to improve the production process, combined with job security guaranteed by unions, are strongly associated with increased firm productivity’. The form of union representation is also important. In many countries workers in HPWS are represented by enterprise or plant based unions. Where industry-wide unions are represented bargaining occurs on a plant by plant basis. These forms of worker representation permit flexibility with respect to job classifications, career paths, training and payment systems (Florida and Kenney 2000). The other major mechanism for collective worker voice is work councils,

[35] Over the years and across different countries and studies the key features of HPWS have remained more or less constant (Ramsay, Scholarios and Harley 2000; Appelbaum, Bailey, Berg and Kalleberg 2001; Hoffer Gittell, Seidner and Wimbush 2010).

typically comprised of employee, union and management representatives. Zwick's 2004 study of German manufacturing plants found not only that decentralised team based participation had a very strong effect on productivity and other measures of innovation, but that this was reinforced in establishments that had also introduced works councils.

8. Incentives- A key part of HPWS is a 'carrot and stick' approach to innovation where active participation in innovation is expected of team members; ideas and improvements are sometimes rewarded with cash bonuses or other benefits and at a broader workforce level profit sharing or employee share ownership schemes may operate. The level of engagement in productivity and quality improvement is one criterion used to assess individual workers for promotion. Because middle management is recruited from the shop floor this creates a strong inducement for team members to be active in product and process improvement. Another key incentive, as noted above, is a commitment to retain the 'core' permanent workforce in the face of a reduction in output. This generates loyalty and feelings of reciprocity within workers for the firm.[36] It also leads to longer job tenure, which, as explained in Section 3.2, is associated with higher productivity and commitment by workers to invest in occupational training. On the other hand, in some countries such as Japan and Korea, many firms with HPWS, that are subject like the car industry to big fluctuations in output, engage a proportion of their workforce involved in routine production activities on a casual or contract basis. (By contrast in other countries such as the UK and US there is a negative association between the presence of HPWS and the use of casual and contract labour). There are marked differences in pay and employment conditions between the firm's core and this 'peripheral' workforce and this serves to enforce discipline among permanent workers who are motivated to retain their employment status. The commitment to continuing employment of the core workforce is based on an 'understanding' not a contract and, over the last two decades has come under increasing pressure (Morishima 2001).

9. Capturing Learning- Devolution of responsibility for innovation is accompanied by measures to monitor, evaluate, capture and diffuse improvements that are devised in one team to others and potentially to operations around the globe in the case of multinationals. This has been described as 'an internal process of variety generation, screening, retention and diffusion' (Fujimoto, 2000: 276). A key aspect of this process is converting the insights of individuals and teams into 'organisational learning' which 'resides in new patterns of activity, in 'routines', or a new logic of the organisation…routines are patterns of interactions that represent successful solutions to particular problems' (Teece, Pisano and Shuen, 2000: 344). Capturing learning involves not only converting currently implemented practices into standard operating procedures but also translating tacit into explicit knowledge. For example, one case study of the sales workforce of a multinational drug company revealed large and persistent differences in the performance of their salespeople despite them receiving the same initial training. A long term study of the different methods of high and low performing salespeople revealed subtle differences in approach and knowledge. This was subsequently incorporated into revised training and 'contributed to continuous innovation at an organizational level' (Monika, Sasaki and Ahmed, 2003: 889).

10. Extensive Training- Broader based occupational classifications and participation in product and process improvement such as undertaking root cause analysis of defects and Quality Assurance requires not only occupational specific technical skills bit also higher level problem solving skills.[37] It is well-established that firms implementing a broad cluster of HPWS elements have a

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36 Surveys of employees in the UK, across a range of industries, including service industries, show a strong correlation between worker commitment and job security. These studies found that 'relationships of trust play a vital role in maintaining the flexibility, morale and motivation of employees' (Mankelow 2002: 153).

37 Root cause analysis is determining the fundamental cause of a problem rather than dealing just with the effects of a problem. An example of the latter is using high labour turnover to find someone suitable to do a

much higher rate of training across all occupational groups (Whitfield 2000). Again longer job tenure makes it economic for both firms and employees to invest in training as both parties can expect a return on their time and effort. Union presence is also associated with a higher probability of training provision (Arulampalam and Booth, 1998).

In reality, of course there is great variation in the extent to which firms implement the full suite of HPWS characteristics, so that most innovating and indeed, non-innovating firms can be represented as being on a continuum from complete to minimal implementation.

3.3.2 Growth of HPWS

The development of HPWS is argued to be driven by similar factors that lead firms to increase their expenditure on innovation more generally. These factors are intensifying competition, including increased price and quality competition from developing countries. Secondly, ICT is affecting not only what goods and services are produced but how they are made and delivered. For example, ICT when integrated into machine tools permits not only faster rates of production but improved quality through closer tolerances and greater customisation by making small batch production profitable. Firms are responding to intensifying competition and exploiting the potential of ICT by measures such as lifting their own quality standards, increasing design intensity and customisation of products and services to better meet customer needs and reducing ‘cycle times’ for the creation and bringing to market of new products and services. Thirdly, on the demand-side, growth of per capita income in developed and developing economies gives rise to consumer demand for higher quality and more customised goods and services. Fourthly, rising educational attainment of the workforce creates not only a potentially more flexible labour force but also one with higher expectations in terms of their involvement in decision-making. Finally, the rise of more decentralised industrial relations systems, based on firm rather than industry-level bargaining, has given employers greater flexibility to introduce new forms of working (Gospel 2007).

3.3.3 Key workforce skills for HPWS

HPWS requires ‘a commitment to innovation at all levels of the workforce, not just at the top’. The process of innovation within HPWS is:

> *“Much more inclusive, ‘democratic’ and incremental, rather than elitist, imposed and radical. By empowering their relatively well-educated workforces to make changes…[firms take] advantage of…‘learning by doing’ and ‘learning by using’ on the shopfloor to make incremental improvements in the efficiency and reliability of production. These forms of improvement are denied in a command and control organisation structure” (Tether et al 2005: 76).*

A broad range of skills has been identified as necessary for successful implementation of HPWS. Aside from key technical skills, a variety of cognitive and behavioural attributes is required. These include:

- Good social skills and communication skills.
- Leadership, initiative and accepting responsibility for one's own work and that of the team.
- Constant vigilance regarding quality.
- Teamwork, cooperation.
- Flexibility.
- Analytical skills and creative problem solving.

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particularly onerous job rather than redesigning the job so that it is less repetitive or physically demanding (Flaherty 2000).

- Capacity to learn and capacity to teach others in a team (Lafer, 2002; Keep and Payne, 2004; Martin and Healy, 2008).

3.3.4 Criticisms of HPWS

The literature on HPWS makes a persuasive case for the critical role of work organisation in fostering innovation within firms. Despite this the claims of HPWS have been subject to two broad criticisms. First, the practice of HPWS is not very widespread. Keep and Payne (2004: 66) argue there is little evidence, at least within the United Kingdom, for a generalised rise in the number of firms that have adopted the full suite of HPWS human resource practices. A similar case is made by Martin and Healy (2008) for Australia. Lafer (2002: 144) also rejects the view that there is a strong tendency to implement HPWS in the US. Such a result is not unexpected, as it will be recalled that at any point in time only a minority of firms are actively engaged in innovation and, moreover, the great bulk of innovation effort is directed at relatively minor, and often one-off, alterations to products, services and processes. Such relatively minor alterations are unlikely to require significant work organisation restructuring for their genesis or to demand such restructuring for their implementation. Hirsch-Kreinsen's (2008: 30) study of 43 low-medium technology companies engaged in incremental innovation across nine EU nations found a 'dominance of Tayloristic forms of work organization' entailing 'a concentration of knowledge in the hands of a small group of managers and technical experts while the more or less qualified production workforce is only responsible for carrying out tasks'. HPWS was only evident in a minority of firms that were focussed on process innovation, and especially the use of advanced automated production and control systems, which required highly trained and relatively autonomous production and maintenance workers (Hirsch-Kreinsen 2008: 32).

Second, more generally it has been argued that intensifying competition can result in firms shifting either to a high innovation strategy using practices such as HPWS or to a low road approach of cost cutting and work intensification. These competitive pressures include increased pace of technical change, rising import penetration, short-termism in investment, a shift in the competing balance of corporate interests to 'share holder value', increased propensity to liquidate and trade assets and deregulation of labour markets and industrial relations (Burchell, Ladipo and Wilkinson, 2002: 5).[38] Firms can respond through a focus on numerical and wage flexibility by minimising labour input through redundancies, use of non-standard forms of employment such as temporary, casual, part-time and contract labour and outsourcing functions domestically and internationally. Such strategies can limit the growth of workforce skills. There is empirical evidence across developed countries that workers on non-standard forms of employment are significantly less likely to receive employer funded training or to invest themselves in the acquisition of skills for jobs which have uncertain employment outcomes (Mangan 2000; Toner 2006).

[38] Whilst not directly focussed on HPWS a recent finding on trends in the work organisation of European firms is consistent with this result. The study found that 'for the EU15 on average, there has been a slight downward trend over 1995-2005 in the percentage of employees having access to work settings characterised by high levels of learning, complexity and discretion. When structural factors are taken into account...this decreasing trend in work complexity grows in size and significance. This result is surprising given the emphasis placed in the European Union on policies for constructing knowledge-based economies' (OECD 2010: 10). This has given rise to the 'task complexity paradox...[because] the increasing level of education, the growing experience of an ageing workforce, the shifts in sector and occupation shares and the diffusion of computers should drive the expansion of jobs with complex tasks, high discretion and learning, but this is not what is observed'(OECD 2010: 17).This is attributed to a broad range of factors such as growth of non-standard employment; investment in ICT permitting enhanced monitoring and standardisation of work tasks and outputs and workers feeling over-qualified for their job (OECD 2010: 89-117).

In summary, the critical literature proposes that ‘technology is not an independent force that automatically leads to more autonomous and higher-wage work. Rather technology always develops within a given political and economic context’ (Lafer, 2002, pp.71-72). This context is the particular competitive strategy adopted by firms and the broader labour market and institutional context which facilitates or inhibits the pursuit of a ‘low or high road’ strategy.

4. CONCLUSION AND POLICY IMPLICATIONS

There are eight key messages that emerge from this overview of the principal themes in the literature on workforce skills, knowledge and innovation.

First, this overview confirms the finding of Bruland (2003) that a "strong connection between education and economic development has often been proposed, but the content, mechanisms, and outcomes of the link remain a matter of debate". A multiplicity of linkages between knowledge, skills, education and innovation were identified in this overview but there are many others, which were not canvassed, that deserve brief mention here. For example, the strong historical association between rising education levels and declining fertility is a critical factor in lifting the capacity for innovation as it permits the accumulation of both human and physical capital (Galor, 2008). Employment in more skilled occupations and higher levels of education are also associated with lower rates of crime and social disorder, that is to say, with security of person and property, which has long been recognised as a *sin qua non* for development (HM Treasury, 2004).

The difficulty in quantifying the relation between skills, education, knowledge and innovation is that each of these variables can be specified in many different ways through a range of proxy indicators, and because of quality differences, there are major difficulties in comparing these variables over time and across countries. It is also the case that changes in the level and type of workforce skill are the result of many causes, of which technical change, or innovation more broadly, is only one. For example, change in workforce skills arise from alterations in international trade, migration, shifts in domestic consumer tastes and movements in per capita income. An example of the latter is the rise in demand for specialist medical services as per capita income increases. There is also no simple or unambiguous connection between a given innovation or technology and the demand it makes for skills. How a technology is deployed is mediated by many factors, most notably as demonstrated in this review, by firm strategies and work organisation methods. Moreover, the direction of causation is ambiguous: skills and knowledge are both an input and output of innovation. Implementing a particular innovation often requires training a workforce and use of a given innovation by the workforce in production and consumption gives rise to incremental improvements to the original innovation.

Second, despite these difficulties it is clear that there is a strong circular and cumulative interaction between knowledge, skills and innovation. "When more skilled workers exist, the market for skill-complementary technologies is larger. More of these technologies will thus be invented and they will be complementary to skills promoting faster upgrading of the productivity of skilled workers." In other words, "an increase in the supply of skills can generate skill-biased technical change" (Kim, 2002: 105). On the other hand, technical change, especially ICT, is also associated with job polarisation or growth of employment in both higher and lower level skills. This is due to the complementarity between ICT investment and non-routine cognitive and manual skills.

Some of the mechanisms identified in this review that promote a self-reinforcing interaction between growth in knowledge, skills and innovation include:

- Growth in the 'volume' of productive knowledge requires ever higher workforce skills to identify, assess and implement new knowledge to the needs of particular firms. The capacity of a workforce to absorb new technologies and to implement and improve these technologies depends not only on its current level of education and skill but also on the rate of investment in improving these skills.

- More skilled workers have greater 'functional flexibility' at work as their greater stock of knowledge increases the rate at which they learn and develop higher order problem solving skills.

- Firms that invest in innovation also have a higher propensity and intensity of investment in workforce training than firms that do not innovate.

- An increase in the overall skill level of a population, such as a rise in numeracy, literacy and scientific understanding, permits an increase in the complexity, variety and technical sophistication of products and services consumed. Related to this argument, there is a strong positive association between education, skill and per capita income both within and across countries. Higher income is also associated with an increased demand for variety, novelty and customisation of products and services. Higher income therefore is associated with an increased demand for innovation in products and services and a capacity to pay for innovation. More skilled and educated people also have higher rates of workforce participation and so have more opportunity to contribute to innovation.

- Investment in education and work-related skills is cumulative. Higher levels of education and higher level occupations are strongly associated with higher rates of participation in employer-funded training. Additional work-related training is, for the reasons outlined above, plausibly linked to increased capacity for innovation.

- Improvement in the quality of skills through education, training and experience and improvements in the quality of ICT and capital goods underpins the complementarity between capital and labour that is revealed in the long-run increase in the capital-labour ratio. Additional capital per worker and more specialised and flexible equipment enhances the scope for product, service and process improvements.

Third, a broad range of workforce skills and occupations are involved in the implementation of innovation. This is because innovation encompasses a very broad range of economic activities which require the engagement of many different occupations. These skills are not restricted to scientific and engineering occupations but involve, for example, direct production workers, tradespersons, technicians and people in marketing, financial management and human resources. The involvement of a very broad range of occupations is also due to the fact that incremental change in products, services, processes and organisational structures is the predominant form of innovation. Such change relies largely on learning by doing and learning by using, or workers reflecting critically on the tasks they undertake, the equipment and software they use in supplying a good or service and on the design of the products and services they make.

It will be recalled that the great bulk of innovation by firms entails the implementation of improvements that have already been implemented by competitors or in other industries. That is to say, the primary form of innovation involves the diffusion and adaptation of existing technologies.

Four, the above points to the importance of broadly distributed capabilities across the workforce. This review identified the critical importance of quality primary and secondary schooling in providing an essential foundation for developing higher level workforce capabilities. However, in some developed economies a surprisingly large proportion of the workforce lacks functional literacy and numeracy skills. Ensuring equity in access to quality primary and secondary schooling is essential to remove the large variation in the attainment of basic skills to be found in many countries in the OECD. Having a large minority of a population with very low literacy and numeracy skills represents a significant constraint on the capacity for innovation. The evidence for this is indirect but it is the case that countries with the largest variation in level of ability in basic skills also have the highest degree of income inequality (Nickell and

Layard, 1999; Blau and Kahn, 2003).[39] This reflects in part the low productivity of workers with limited assessed cognitive abilities. Having a significant share of labour supply with these low basic skills also constrains some industries and firms to a low-skill equilibrium.

By contrast innovation that is close to the technological frontier relies on advanced scientific, engineering and management skills. The more dependent an economy is on this form of innovation the greater the necessity for higher level 'elite training'.

Five, aside from improving the level and distribution of school outcomes appropriate incentives and obligations are essential to overcome the deterrent for both firms and workers to invest in transferable intermediate level occupationally specific skills. 'Matched plant' studies have shown the profound effect of differences in the quality of intermediate level skills on productivity, quality and innovation. The UK government in particular has acknowledged the adverse effect that an inadequate training rate and variable quality of vocational training has on the UK innovation system. The public policy response to this problem is, however, not at all transparent, and may possibly represent an intractable dilemma. This is because the development of a large-scale, high quality system of industry based vocational training, as typified by Germany, would require the replication of a broad range of corporatist institutional arrangements, that are possibly incompatible with the UK flexible labour market and neoliberal institutional arrangements. On the other hand, the flexible labour market model and a large supply of world-class university graduates is particularly well suited to other forms of high-skill innovation as represented by the success of the United Kingdom in finance, creative industries, software, pharmaceuticals and aerospace.

Six, workforce skills are a necessary but not sufficient condition for successful innovation. There is considerable evidence that the type of work organisation adopted by firms is a critical factor in encouraging or retarding the engagement of workers in various forms of workplace improvement. The type of work organisation is also a critical factor in determining firms' demand for higher-level skills and investment in training. The literature also reveals that in responding to intensifying technological, price and quality competition there is no inevitable tendency by firms towards the wide-spread adoption of practices such as 'High Performance Work Systems'. Rather firms and economies are confronted with conflicting and sometimes contradictory choices and practices. For example certain labour market practices which are increasingly the norm across the OECD, especially the rise of non-standard forms of employment such as casual, contract and part time jobs, and practices that result in higher labour turnover, are associated with both lower employer investment in worker training and lower investment by workers themselves in their own education and training. Job security has been found to promote knowledge sharing between workers and greater acceptance of technical change within workplaces.[40] Whilst there are undoubtedly benefits to greater labour market flexibility, in terms of reallocating resources across industries in response to price signals and adjusting resource use to the level of demand, it must also be recognised that these practices can also impose some constraints on the capacity for innovation. The literature has also established that the choice of work organisation is strongly influenced by broader national institutions governing the labour market, education, innovation and social policy.

Seven, demand for higher level workforce skills depends on the growth of technically progressive and adaptive firms and industries. Public policy can promote the development of such firms and their workforce through a variety of mechanisms. One of the most important are technology diffusion

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39 Variation in ability was measured as the difference in scores on standardised literacy and numeracy tests between the median and ninth decile.

40 There are important exceptions to this finding. For many professional occupations, such as medical locums, computer programmers and engineers contract employment is common. The exposure to multiple workplaces, technologies and problems is an acknowledged source of professional development and knowledge transfer.

programmes which not only expose ‘frontier firms’ to leading edge technologies but also seek to raise the capability of the average firm. Ensuring broadly distributed capabilities across the workforce depends on the efficiency of technology diffusion within a country, region or firm. “Technology diffusion involves the dissemination of technical information and know-how and the subsequent adoption of new technologies and techniques by users… In many cases, diffused technologies are neither new nor necessarily advanced, although they are often new to the user” (Shapira and Rosenfeld, 1996). The most common example of government technology diffusion programmes are agricultural extension services where, for example, state sponsored agronomists provide advice to farmers to improve yields, control pests and reduce input costs. Many governments have also established services designed to lift the productivity and innovation performance of SME manufacturers in particular. These firms are argued to be subject to market failure in their capacity to search and evaluate potential productivity and innovation enhancing techniques. This is principally due their small size and limited internal specialised ‘information processing’ capacity. Manufacturing industry is also argued to be subject to an especially fast rate of technical change that itself imposes high search and evaluation costs. For example the U.S. Department of Commerce for some decades has run the Manufacturing Extension Partnership (MEP) Program and was favourably evaluated (National Academy of Public Administration 2003. See also http://www.nist.gov/mep/). Similar programmes operate in the UK as the Manufacturing Advisory Service (UK Department of Trade and Industry 2007).

Eight, it is important to avoid the fallacy of composition that because the returns to higher skills apply to a large proportion of the workforce it does not hold that if all workers gain these skills the returns will remain the same (Lafer, 2002: 61; Wolf 2004). In other words, just because the average level of skill in advanced economies may be rising it does not follow that this applies across all industries and firms. Public policy with respect to investment in skills upgrading must be based on a sober assessment of labour demand for higher level skills.

4.1 Areas for more research

One of the key conclusions of this and other studies is that, despite recognising the central role of higher level and more broadly distributed workforce skills in promoting innovation, there has been little research within the field of innovation studies on this topic. Much of the effort has been directed at improving the theoretical understanding of the properties of ‘knowledge’ and ‘information’ and its role in economic growth or econometric studies in which various specifications of technical change are employed as an independent variable to ‘explain’ a broad range of structural changes in the economy. Accordingly, the following are suggestions for further empirically oriented research.

First, one potentially fertile subject for more investigation is to examine the role and contribution of particular occupations to different *innovation activities* such as R&D, commissioning, installing and optimising capital equipment or software and devising, designing, prototyping new or improved products and services. This could also involve investigating which occupations are the source of the original idea for the innovation and which are responsible for its development and implementation. In addition, such studies could examine these activities across different *forms of innovation* such as incremental to radical innovation and high tech versus low tech innovation.

Second, what changes in occupational structure, scope of tasks and knowledge base of workers occur during and after the process of implementing significant changes to products, services and work organisation?

Third, a key result of matched plant studies and the literature on national differences in skill formation systems is that “there are different routes to national economic competitiveness which make quite different demands on skills” (Green and Sakamoto, 2001: 148). Most of the existing literature on matched plants dates from the 1980s and 1990s and since this time there have been important new technologies or changes to production methods in developed economies such as the Internet, e-commerce and dramatically increased outsourcing of lower-skilled and/or high-volume, standardised activities to developing countries. In light of these significant changes there is considerable merit in undertaking a large programme of research to examine whether the stark differences that emerged across countries, especially in the quality of intermediate skills, still apply and whether a different suite of skills and knowledge underpin any currently observed differences in productivity and scope for innovation across firms.

Finally, high-quality primary and secondary schooling that minimises variance in a population's educational and cognitive attainment has been argued to be an important factor in precluding the development of large parts of an economy marked by low productivity, low wages and low innovation. Research is warranted to explain the factors that lead to both high average level of attainment and greater equality of outcomes from schooling.

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