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Innovation and Vocational Education

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Abstract

This article reviews the arguments and evidence on the role and contribution of the vocationally trained workforce and vocational training system in technical innovation. The primary focus in terms of the vocational workforce is on skilled production workers and, in particular, tradespersons and technicians. These occupations and the vocational training system are found to have a unique role and make a significant contribution to innovation in both production and Research and Development (R&D). The primary role of the VET system in innovation is technology diffusion. However, there are a number of impediments to achieving this role. These are sustained budget cuts and exclusion of the VET system from national innovation policy, programmes and advisory structures. The latter is attributed largely to the failure of the innovation studies discipline, which has strongly influenced government policy in this field, to study in detail the role of VET occupations and training system in the innovation process. This conclusion is paradoxical as the discipline's own analysis of innovation makes a compelling case that these occupations and training system should be central agents in this process.

Keywords

Vocational education; innovation; tradespeople; technicians.

Introduction

The innovation studies literature represents something of a paradox. On the one hand it emphasises the important contribution of incremental innovation to economic growth. It emphasises the central role of learning as a driver of incremental innovation, and the predominance of Development over Research in business R&D spending. It recognises that 'low-tech' mature industries both are not only the largest sources of employment and output in advanced economies, but account for a large share of innovation expenditures (Smith 2004; von Tunzelmann and Acha 2005; Hirsch-Kreinsen 2008). The innovation literature points unambiguously to the potential importance of skilled production, trade and technician occupations in technical change, given their central role in designing, installing, adapting, operating and maintaining capital equipment, software and consumer goods (Toner et al. 2004). On the other hand, the innovation

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literature has, over the last three decades, largely ignored the role of the direct production workforce in innovation:

> 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)

Similarly, studies of the 'knowledge economy' workforce have focussed on the 'highly skilled', professional and managerial occupations, and studies of the 'R&D workforce' have focussed on scientists and engineers (Hohlfeld 2008; Shapira 1995).[1]

This article provides a summary introduction to the concept of innovation and overview of the arguments and evidence for the role of VET trained occupations and the VET training system in innovation. The principal focus in terms of 'VET occupations' is on trades and technicians and that part of the 'VET system' which trains them. The goal is to be comprehensive in terms of presenting the key ideas, but the overview is not exhaustive in terms of citing the many authors that have contributed to these arguments.

The argument is structured as follows. Section two defines innovation and uses official survey data to illustrate the significance of VET trained workers in the innovation process. Section three describes the role of the VET system in the national innovation system and the impediments to fulfilling this role.[2] Section four briefly summarises the arguments and evidence on the role of VET in innovation drawn from studies of the political economy of national skill formation systems.[3]

Defining Innovation

The official conceptual framework for analysing and undertaking empirical work on innovation, the *Oslo Manual* (OECD and Eurostat 2005) defines innovation 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' (OECD and Eurostat 2005: 46). Certain firm expenditures are deemed to be indicators of implemented innovation activity. Examples include R&D; new equipment or software acquired to introduce a new or improved product, service, process or other innovation; trial production and pilot plants; acquisition of patents, technology licences, trademarks; product and process design; marketing of new or improved products and services, introducing business improvement systems and workforce training related to the introduction of innovations. The scope of innovation activity is thus very wide and, correspondingly, the range of workforce skills to implement innovation is also broad.

Radical and Incremental Innovation

Innovation is classified into two broad types, radical and incremental, depending on the objective and outcome of the activity (Pavitt 2005). The distinction between incremental innovation and radical innovation is important in understanding causes of change in the pace and scale of technical progress. But the distinction is also important for the further reason that '... the two types of innovation embody a very different mix of knowledge inputs and have very different consequences for the economy and the firms which make them' (Freeman 1998: 30).

Radical innovations typically are subject to great uncertainty both over the course of invention and in relation to the size, or even the existence, of a potential market. They 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. They are 'disruptive'; in Schumpeter's famous formulation, they generate 'gales of creative destruction' by making existing markets, products, production systems and skills technologically redundant (Abernathy and Clark 1985). Over the course of the last century they have been 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: 4, 23). 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).

Similar principles are at work in process innovation, where continuous improvements, optimisation and cost reduction of materials and components have been associated with competitive success of firms and nations. Incremental innovations typically use existing technologies and standards to effect improvements to existing products, services and production processes. They have more predictable development costs and market potential and can be undertaken by a broad range of businesses and firms, as it does not necessarily require large investment to develop or implement. Critically, they are often inspired and developed by direct production workers as users or producers of a good or service. 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). They are also the result of improvements suggested by final consumers of goods and services (von Hippel 1988, 2005).

Radical and incremental innovations are clearly linked, as the former 'typically come in to the world in a very primitive condition. An extensive improvement process, the details of which can hardly be known at the time of invention vastly expands the applications of the technology' (Rosenberg 1994: 4).[4]

A key implication of the prominence given to incrementalism is that it has largely displaced the earlier 'linear' or 'science-push' model of innovation in which technical change was assumed to seamlessly flow from basic scientific research to applied research and then into production and diffusion (Godin 2005). On this last point Scott-Kemmis (2004: 70) has argued that:

> [w]hile 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.

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 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: 121–122; 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.

Workplace learning can be accelerated and captured by certain practices. This entails 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 best practices into standard operating procedures and translating tacit into explicit knowledge, but can also be promoted by workforce 'experimentation'. For example, Thomke (2003) describes how firms selling intermediate inputs (goods and services that are sold to other firms rather than to consumers) provide software tools to customers to encourage experimentation with products and services. Other research identifies how organisational learning, targeting process control and quality improvements and systematic experimentation by post-war East Asian firms allowed late entrants into markets and late adopters of technologies to catch up with first movers. This research has also identified the critical role of tradespeople and technicians in this learning (Hayes and Wheelwright 1984; Nonaka and Takeuchi 1995).

Pattern of Australian Innovation and R&D

Regular official surveys are conducted of innovation and R&D activity in Australian business. The pattern of innovation and R&D in Australia confirms the centrality of incremental innovation as businesses report overwhelmingly that their innovation activity involves copying or adapting improvements from similar firms or from other industries. Less than one per cent of innovating firms report that there innovation activity is 'new to the world' (ABS 2006a). The importance of learning by doing and using is also supported, as the most common sources of ideas for innovation that businesses identify are from inside the firm and from customers, suppliers and competitors (ABS 2008). Other sources, such as universities and research institutes, are used infrequently. The importance of certain VET occupations is also directly supported. Firms were asked to select from nine broad occupational groups those they 'used for innovation activities'. These occupations included, for example, Trades, Engineering, Scientific and Research, Marketing and Finance. For industries in which Trades are a significant share of the workforce — that is, Manufacturing, Construction and Other Services (of which repair and maintenance of machinery and equipment is a large element) — Trades were, by a large margin, the most frequently cited source of skills used for innovation. The survey also asked innovating firms to identify which occupations they used to undertake innovation were in shortage. Across all industries, not just the three listed above, Trades are the most frequently cited occupation used in innovation that is also in shortage (ABS 2008).[5]

More broadly, innovation activity in Australian business is not comparatively R&D-intensive but is concentrated in a range of low and medium technology activities. Australia ranks 14th across the OECD in terms of Business R&D as a share of Gross Domestic Product. Australian business investment in R&D would need to double to match the highest performers (DIISR 2010: 45). Australia ranks 28th across the 33 OECD countries in terms of the share of high and medium-high technology output in manufactured exports (DIISR 2010: 49). The significance of this data is that, compared with many other developed countries, Australia relies primarily on means other than R&D for technological upgrading. For example, in 2006–07 acquisition of machinery equipment, software and hardware was the most frequent type of innovation expenditure, undertaken by 48 per cent of innovating firms. Just 15 per cent of innovating firms incurred any expenditure on R&D (ABS 2008). There is evidence that investment in new plant and equipment is inversely related to R&D: 'firms that have relatively low R&D shares [as a proportion of their total innovation expenditures] have higher investment shares' (Smith 2004: 37). More generally, it has been argued that:

> Australian firms are largely users and adaptors of core technologies and as such could be termed 'systems integrators'. This is a particular capability to add value by integrating or assembling systems, resources and technologies rather than involvement in their development. The core competencies of systems integrators, relate to project management, logistics, problem solving and adaptation to particular circumstances. (Scott-Kemmis 2004: 69)

It should be noted that these are core competencies for trade and technician occupations. (The following sections consider this in more detail).

So far it has been argued that the official definition and measurement of innovation in the OECD suggest that a great variety of skills, knowledge and occupations, including VET occupations, are involved in innovation. Second, modern research on innovation has arguably identified minor improvements and gradual optimising as the primary sources of technical change, with the direct production workforce playing an important role in the process (although this role has not been subjected to detailed analysis). Third, it has been suggested the extent of the involvement of the direct production workforce in innovation within firms depends on work organisation practices that encourage, reward and capture workplace learning.

The role of VET in Innovation

This section briefly discusses the role of VET occupations and the VET system in the Australian national innovation system. It also identifies the principal impediments to fulfilling this role. As noted in the introduction the focus here, in terms of 'VET occupations is primarily on tradespersons and technicians. Accordingly, it is important to define, in general terms, the scope of activities undertaken and skills attained by these occupations. The following is derived from the *Australian and New Zealand Standard Classification of Occupations* (ANZSCO):

> Technicians and Trades workers perform a variety of skilled tasks, applying broad or in-depth technical, and trade or industry specific knowledge, often in support of scientific, engineering, building and manufacturing activities. (ABS 2006b: 335)

ANZSCO provides a description of the broad range of industries and activities in which technicians and tradespeople are engaged. A key role of these occupations is to *design, instal, commission, adapt, operate and maintain* equipment, software and other technologies (Toner et al. 2004).[6]

The contribution of the skilled VET workforce to innovation is not limited to its role in direct production. Across the European Union and Australia, around 45 per cent of the business R&D workforce is comprised of VET qualified workers, mostly technicians and tradespersons. A recent large scale study of the role of tradespeople and technicians employed in Australian R&D labs found they make a significant contribution to the performance of R&D. This reflects their particular practical skills, knowledge and approach to problem-solving (Toner 2011).

The VET system is remarkably varied and diffuse. It can broadly be defined as the delivery of post-school, non-university education and training by public and private sector entities.[7] The system is important in workforce education and training. In 2007, 60 per cent of the total Australian workforce had a post-school qualification, as recognised by the Australian Qualification Framework, of which 60 per cent were below the level of a bachelor degree (ABS 2007: Table 11). In 2006, around 1.7 million people enrolled in publicly funded VET courses. Around 12 per cent of the total population aged 15–64 undertakes VET training at some point in time over the course of a year; with about 80 per cent of these enrolled at TAFE (Skills Australia 2010a: 26).

Technology Diffusion

The effectiveness and efficiency of key innovation processes, learning by doing and using, and the capacity of the direct production workforce to engage creatively in problem solving depends critically on widely distributed technical competence. The depth of technical competence in a workforce depends to a large extent on the efficiency and effectiveness of mechanisms for technology diffusion.

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> 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: 1)

There are many other sources of innovation and technology diffusion, such as new technology embodied in new vintages of equipment and software; consultants; competitors; mobile skilled labour; industry associations; trade and scientific press and reverse engineering. Nevertheless, in Australia the VET system plays a critical role in technology diffusion and raising the 'absorptive capacity' of the workforce by imparting practical skills and underpinning knowledge (Cohen and Levinthal 1990). Technology diffused by the VET sector is not necessarily 'new' or 'advanced' but, crucially it is 'new to the user':

> The Australian system of innovation fits the pattern of incremental innovation and diffusion of technical knowledge. Historically, from colonial times to the advent of the present national system, the technical education and training institutions, for all their historically specific characteristics, industry critics and state differences, have functioned to support this process. (Pickersgill 2005: 7)

VET teaching institutions are particularly suited to the role of technology diffusion for a number of reasons. They have a more explicit economic development role than universities. Within the vocational education and training sector, there is a strong focus on meeting the particular needs of industry and of students in the region in which the colleges are located. Colleges, moreover, have a direct link to the investment activities of firms through their role in training employees. Because of this responsiveness, demonstrated in the rapid development of customised training, VET colleges arguably have greater adaptability than universities.

In a review of the knowledge diffusion role, within the OECD, of technical colleges such as the TAFE system in Australia, Rosenfeld (1998: 4-8) identified three distinct roles for VET institutions. The first is technology diffusion through teaching. In Australia, as elsewhere, the principal role of VET institutions in the national innovation system is one of technology diffusion by imparting to the workforce both practical skills and underpinning knowledge of production processes. Second, VET can act as a technology intermediary. Technical colleges have an 'under-rated and undervalued contribution' in their role as 'intermediary institutions … putting companies and services in touch with one another and encouraging technology transfer and information exchange' (Rosenfeld 1998: 7). For example, some VET teachers promote the use of colleges as venues for vendors of equipment and software to demonstrate their wares to local business. Finally, in many regions without universities or other public science and research agencies, colleges are the leading source of technical expertise (Rosenfeld 1998: 6). These functions are especially vital for 'small and medium sized employers, whose requirements for technology and innovation [are] something less than leading-edge research and who … [lack] the capacities and connections to effectively adapt already commercially available technologies

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and proven innovations' (Rosenfeld 1998: 2). Toner (2005) provides examples of TAFE teachers in metal, electrical, computing and metallurgy fields assisting firms to improve product design and production processes. Whittingham (2003: 72) found that 'applied research and development is not something for which the VET system has a reputation, but it is occurring in many colleges. This is a specific but unharnessed VET capability which could be developed more fully to assist in the innovation capacity of the nation'.

While across Australia, VET plays an important role as a technology intermediary, assisting firms in applied development, it is nevertheless important to recognise that this role largely involves discretionary activity and is dependent on the initiative of individual colleges and teachers. The central role of VET in the Australian innovation system is knowledge diffusion primarily through teaching. The role of VET differs from other elements in the innovation system such as universities, CSIRO and Co-operative Research Centres as these have an explicit dual function of knowledge creation through research and knowledge diffusion through teaching and/or consulting to business.

Impediments to VET System's Role in Innovation

The literature, on the other hand, identifies a number of impediments to the success of the VET sector's successful performance of its technology diffusion function. Whilst the following examples are taken mostly from the Australian case, similar problems are found in the VET systems of other advanced economies (Rosenfeld 1998; Hoeckel and Schwartz 2010).

First, there is a variety of problems in Australia arising from declining real funding for the VET sector, especially TAFE. Between 2004 and 2008, government recurrent expenditure on publicly funded VET training fell 11.5 per cent per hour of training (in 2008 prices) (Skills Australia 2010b: 57). 'This decline in funding per student contact hour raises concerns about quality and the ability of the sector to innovate' (Skills Australia 2010b: 6). Resource constraints inhibit innovation for a range of reasons, including the following:

- Reduced staff numbers and low recruitment rates have resulted in an aging VET workforce. The imminent retirement of a high proportion of the permanent VET workforce will result in the loss of experienced teachers and their industry networks. An aging VET workforce also means that fewer full-time teachers have had recent direct employment in industry. This is exacerbated by cuts to 'return to industry' programmes which allow teachers to spend time in firms updating their skills and knowledge. These problems are redressed to some extent by greater use of casual or part-time VET teachers sourced from those currently employed in industry. On the other hand, given the estimate that nationally, over half of TAFE teaching practitioners are casual, '... a key issue is that they generally have less access both to ongoing support from other VET staff and to professional development opportunities' (Guthrie 2010: 10). The increased administrative burden of coordinating and administering a fragmented contingent workforce is seen as leaving head and other permanent teachers with less time to play an innovation-mediating role with local industry.

- Resource constraints have also led in many States to the abolition or reduction of the role of central agencies in collecting and disseminating information on new technologies and developing learning materials supporting the use of recently acquired technologies. The decline in central agencies has reduced the efficiency of knowledge flows and led to duplication of effort across a decentralised system.
- Over the last decade, intrastate and interstate competition for scarce training funds, both among public colleges and between public and private colleges, has reduced the incentive for managements and teachers to share information and resources.
- There has also been increased difficulty in maintaining the currency of equipment and software, owing to the cost and increased rate of technological redundancy (Toner 2005, 2008a, 2008c).

Second, there are generally poor linkages between the VET sector and firms and institutions that develop and implement 'emerging technologies' (Whittingham 2003; Toner 2005). The VET system necessarily focuses its teaching activities on technologies which are widely implemented and for which there is a stable and predictable level of student demand. These are technologies with well established technical standards and protocols for operation and maintenance and strong supplier networks. However, constrained funding for VET has reduced its ability to invest in longer term activities that have uncertain outcomes. The broadening of networks between teachers and researchers is an example of the sorts of activities less likely to be undertaken. This is despite the acknowledged benefits of closer links between knowledge producers and vocational education and training which include

> … more timely skills development in new and existing industries … better knowledge transfer into the training system to support industry development … a reduction in the likelihood of skills gaps or shortage … [and] a culture of innovation in the VET sector. (Ferrier, Trood and Whittingham 2003: 87)

A third impediment, common to many OECD nations, is thought to be a long run decline in the academic ability of VET students, due to an increasing share of school leavers entering university (Toner 2005; Hoeckel and Schwartz 2010). This is also a particular problem in many North Asian developed economies (Ashton, Green, Sung and James 2002).

The central role of VET in technology diffusion has been argued to have been undermined to some degree by the adoption, from the UK over the last two decades, of Competency Based Training (CBT). There is not the space to detail the debates around this claim, but the basic argument is that CBT gives excessive emphasis to the imparting and assessment of practical skills at the expense of integrating these skills with theoretical underpinnings. It is suggested that this reduces the capacity of workers to deal with novel problems and engage in problem solving (Toner 2005; Guthrie 2009). CBT has also been applied to the training of VET teachers. Over the last decade in Australia the minimum pedagogical qualification requirement for permanent VET teachers has been reduced from a Diploma in Education to a Certificate 4 in Teaching and Assessment. The latter qualification is itself based on CBT principles and only covers the requirements for the collection of evidence for competency based assessment. This means that teachers are not in a position to critically reflect on teaching methods in general and CBT in particular. They simply learn how to apply the CBT approach. Guthrie (2010: 23), summarising the results of educational research on this topic, argues that as a teaching qualification the Certificate 4 'should only be seen as a foundational one, which must be enhanced by further experience, formal training and professional development'.

Finally, VET is poorly integrated into innovation policy and advisory structures. For Australian public policy on innovation the VET sector is, in Whittingham's (2003: 72) evocative phrase, 'an undiscovered country'. The most recent external analysis of the Australian innovation system, the 2008 Cutler Review, is itself typical of this trend (DIISR 2008). Despite noting that the 'role of crafts and trades in innovation has been massively neglected, particularly in the important areas of continuing incremental innovation in the workplace' the Review made no further analysis nor recommendations relating to the VET sector (DIISR 2008: 48).[8] VET is also ignored in the federal government's comprehensive descriptions of Australia's innovation system, including the most recent (DIISR 2010). The exclusion of VET from government innovation advisory structures can be measured by examining the membership of all state Innovation Councils (Toner 2008). These Councils provide advice on innovation policies and also frequently manage substantial innovation funding programmes. Typically there are 10–15 members represented on each of these state Innovation Councils. Members include CEOs of high technology firms, senior faculty from university science or business departments, managers of public sector research institutions and government officials. Of the 80 members across all states in Innovation Councils, just 2 formally represent the VET sector. The composition of federal government advisory bodies is similar.

The reasons for largely excluding VET from innovation policy and advisory structures are complex, though two explanations can be offered. The first reflects a bias in the academic tradition of innovation studies which, despite pointing unambiguously to the important role of the direct production workforce largely ignore this role as a research topic. Moodie (2004: 95) has also suggested that '[h]igher education's capture of innovation policy' has resulted in a low priority being given to technology diffusion in Australian Government innovation policy and an excessively high weighting given to R&D, especially within universities.

National Differences in Skill Formation Systems and Innovation

The literature on comparative national skill formation arrangements argues that systematic differences in vocational training systems are associated with particular industrial structures, product markets and innovation strategies. This section briefly discusses three distinct streams in this literature. Each of these streams employs widely divergent methodologies and evidence base, but importantly, all lead to the same broad conclusion, that VET systems profoundly affect the scope and variety of innovation within nations. The first stream deals with different national philosophical and pedagogical foundations of VET. The second are known collectively as 'matched plant' studies. Finally, the literature on the political economy of national skill formation systems identifies a diverse range of inter-locking and self-reinforcing historical, political, economic and social factors that give rise to distinct patterns of innovation. It also briefly considers some of the principal criticisms of this literature.

Divergent Definitions of Skill

There are significant inter-country differences in the philosophical and pedagogical foundations of national VET systems, which, in turn, have been argued to have implications for the capacity of the workforce to engage in innovation. The principal focus of this literature is the divide between the Anglo-Saxon conception of vocational skills and that obtaining in continental Europe, especially Germany, the Netherlands and France.

The main characteristics of the Anglo-Saxon concept of vocational skill stem from an assumption that it is the attribute or property of an individual. This view of skill associates it with physical or manual dexterity and not necessarily with a particular knowledge base. Skill is thus assessed and certified through the performance of discrete practical tasks or 'competencies'. This perspective does not relate skill directly to the possession of a qualification, as formal qualifications are not required for entry into many vocational occupations; nor are wage levels tied to the possession of qualifications (Clarke and Winch 2006: 261).

By contrast, German *berufsbildung* (vocational education) is based on a different conception of skill that recognises production as an inherently social activity in which students are taught how their activities fit in with and shape the performance of other occupations engaged in a production process. Vocational education includes general education in the curriculum through subjects such as 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. Entry into vocational occupations is linked to the possession of specific qualifications and wage levels and increments are tied to the attainment of qualifications (Clarke and Winch 2006: 265).[9]

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).[10] 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 variation in the performance of vocationally trained workers across countries. In the UK, VET workers are seen as 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)

The detailed empirical examination of the mechanisms that translate national differences in VET systems to differences in innovation performance is the concern of 'matched plant' studies.

Matched Plant Studies

Over the past decade, a large-scale research project has been undertaken, examining the effect of inter-country differences in the skills and qualifications of direct production workforces on firms' productivity, quality of output and capacity for product and process innovation. The typical comparison is between firms and the training system in the UK, and firms and training in Europe (Germany, France and Holland). This research agenda has included studies of metal product, clothing, kitchen cabinet and biscuit manufacturing as well as hotels (Prais 1995); food processing (Mason, van Ark and Wagner 1996); surgical instruments (Anderton and Schultz 1999); residential construction (Clarke and Wall 2000; Clarke and Hermann 2004) and heating and air-conditioning installation (King 2001).

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 UK in particular has a much higher proportion of the direct production workforce with no qualifications and, those with qualifications are on average credentialed at a lower level than comparators in European workforces. These disparities have been linked to international productivity differences between the UK and European firms in manufacturing of up to 100 per cent in some: in construction, a disparity of 37 per cent has been found.[11]

Several factors have been identified which are thought to translate national differences in the quality and quantity of VET trained workforces into national differences in productivity, quality and innovation. To summarise the findings from these matched plant studies, firms in countries where a comparatively high proportion of the production workforce has higher-level VET qualifications appear to have 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. Quality control based on the rectification of faults in products at the end of the production line was found to be common in British plants. In European plants the employment of more highly skilled production and maintenance persons allowed for more automated control of production processes and closer tolerances of work.[12]

- **Lower ratio of direct to indirect labour:** Employment of more semi-skilled persons in British plants operating within a Taylorist work organisation, in which individual production employees act with little autonomy, necessitated layers of supervisors and management to monitor production and directly manage the introduction of new products and processes.

- **Higher capacity utilisation rates:** The occurrence of higher rates of plant breakdown accounted for a large part of the productivity differences between British and European plants studied. A higher rate of plant breakdown was

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attributed to inadequate plant maintenance in the British plants, and more specifically, to inadequate preventative maintenance programs.

- **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. This contrasts with a dependence on inflexible mass production methods in the UK 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.

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: 38–39).[13]

Political Economy of National Skills Formation Systems

There is now a very extensive literature that identifies a diverse range of interlocking and self-reinforcing historical, political, economic and social factors that give rise to distinct national vocational training and innovation systems (see for example Culpepper et al. 1999; Brown et al. 2001; Hall et al. 2001; Thelen 2004).[14] There is not the space to detail these complexities. The focus here is simply to provide a brief over-view of the three 'ideal types' in the literature and the different patterns of product, service and process innovation with which they are associated. The over-simplifications of the typology are then briefly critiqued.

- **Flexible labour market model:** The 'flexible' labour market and skill formation model (UK and US) is typified by low levels of labour market regulation and unionisation; high rates of labour turnover due to the ease of hiring and firing; enterprise based bargaining; an emphasis on 'numerical' flexibility achieved through a labour market split between a 'core' permanent workforce and a large 'peripheral' workforce. There is 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 intermediate qualifications. Underpinning this skewed skill distribution is 'unequal outcomes of initial education and training' (Green and Sakamoto 2001: 131). The UK and the US have a higher proportion of their adult population that are functionally illiterate and innumerate, compared, for example to Japan and many countries in Europe (Tether et al. 2005: 52–53). The UK and US vocational training system is largely employer controlled and focussed primarily at meeting narrowly defined firm-specific skill requirements (Keep 2006). The extent of occupational licensing for intermediate skills is limited in the UK and US reducing 'the incentives of employers and employees to invest in skills' (Green and Sakamoto 2001: 127). 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

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> 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)

Such a polarised distribution leads 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). Both the UK and US have been effective at innovation based on high level elite skills in science and technology derived from a high concentration of world class universities and innovative capital markets. 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 financial services, management consulting and creative industries like advertising, publishing, design and entertainment (Tether et al. 2005: 70). It is interesting to note that the export volume of these high-skill products from the US and UK is small by comparison with their imports of intermediate-level products. Consequently, both countries run substantial merchandise trade deficits (Crouch et al. 1999: 107).

This flexible skill formation model has given rise to the notion of 'low-skill equilibrium' (Finegold and Soskice 1988; HM Treasury 2004). This 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. 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).

- **Occupational labour market model:** 'Occupational' labour markets, such as the German apprenticeship system, are based on a regulated labour market and close co-operation between employers and unions, supported by government. This system encourages innovation by deterring price competition based on low pay; high wages stimulate capital investment; broadly skilled workers facilitate flexibility in the workplace; long job tenure reduces worker resistance to new technologies and facilitates higher level understanding of a firm's products and processes. A skilled intermediate workforce can engage in complex problem-solving and communicate with a firm's scientific and engineering staff. Underpinning the German vocational training system is a high average level of educational attainment in schools. The occupational labour market model produces vocational skills characterised by 'deep competencies within established technologies' (Estevez-Abe et al. 2001: 174). Such workplace skills are '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). Early analysis of these occupational labour markets are associated them with the concept of a 'high skill equilibrium', or a circular and cumulative relation between the supply of, and demand for, high productivity, high skill vocational occupations (Finegold and Soskice 1988; Streeck 1998).

- **Internal labour market model:** The archetypal model of the internal labour market (ILM) is the large Japanese or Korean corporation (Ashton et al. 2002). 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 rigorous selection tests and receive mostly firm specific training. 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 demarcation) are encouraged by the linking of pay to experience and time served. Job security significantly reduces resistance to the introduction of potentially job-displacing new technologies. Crucial to the high quality and high productivity system of production are organisational innovations that rely on a skilled and committed workforce. In particular the systems of Quality Assurance, Just in Time and reduced cycle times (rapid introduction of new products/processes)

> require a commitment to innovation at all levels of the workforce, not just at the top … By empowering their relatively well-educated workforces to make changes, the Japanese firms took 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 disadvantage of the ILM model of high productivity labour is that, in Japan and Korea, it is restricted to a few industries, notably the manufacturing sector. This contrasts with Germany where apprenticeship training in a broad range of industries underpins high productivity and quality across many sectors (Green and Sakamoto 2001: 65).

Criticisms

These broad typologies have been subject to a variety of criticisms (Hancke et al. 2007). The first challenge is to the idea of stability implied by the idea of 'equilibrium'. This is especially so for the high-skill occupational and ILM models due to intensified competition from low labour cost countries that are capable of closely matching advanced countries for quality (Crouch 2005). Second, countries are not uniform but exhibit characteristics of all three labour market models. This diversity within and across countries points to the inherent arbitrariness in allocating a country, industry or firm to a specific model. Culpepper (2007) for example, showed that in European nations regarded as having 'occupational' and 'coordinated' labour markets there are enormous differences between small and large firms in the level of investment in workforce training. Moreover, small firms are in conflict with large firms over the content of apprentice training to be mandated in national standards with the latter demanding more narrowly focussed firm specific training. Taylor's (2004) analysis of international patent and science citations data challenges the validity of the argument that flexible labour market model is typified by more radical innovation compared to the incremental form claimed to be representative of the occupational model.[15]

Conclusion

The purpose of this article was to provide an overview of the key arguments on the role and significance of vocational education in innovation. Most of the relevant literature, such as the political economy of national skill formation systems, whilst informed to some extent by the innovation studies discipline, is from outside this discipline. Despite observing the importance of the direct production workforce and the training systems which produce it, the discipline has not engaged in detailed studies of the role and significance of VET in innovation. These gaps are however, being increasingly recognised. '[A]cademic research on innovation is still dominated by an R&D mindset, so that the characteristics and drivers of non-R&D based innovation continues to be neglected (Arundel and O'Brien 2009: 22). This deficiency is of more than of academic interest, but arguably has real world consequences, such as the exclusion of VET from Australian government innovation policy, programmes and advisory bodies.

At the same time it is important not to exaggerate the singular role of these occupations in innovation. The key lesson of the systems approach to the study of innovation is that firms operate in a complex ecology of institutions that can encourage or hinder firms and their workers. Innovation also requires complementary policies relating for example to industrial relations, government procurement, tax, industry promotion and export support (Cutler 1992; Keep and Mayhew 2001).

The topic of VET and innovation is an important and fertile, though underdeveloped, field of research. However, it is also an inherently difficult field, because the linkages between 'innovation and training in modern economies … [although] inextricably linked' are also 'reciprocal and complex' (Warner 1994: 348). A variety of disciplines and methodologies, such as those briefly summarised in this article, will be necessary to further deepen our understanding.

Notes

1. The employment effects of innovation have also been closely studied in the innovation literature, though these deal with 'skills' at a high level of abstraction. The principal topics include 'skill-biased technical change' and the opposing effects on employment growth of product and process innovation (Pianta 2005).
2. There are three principal ideas behind the concept of 'national system of innovation'. First, that innovation is not the product of isolated activity within a firm or university department, but the outcome of a set of interlocking institutions including the education and training system; tax and corporation

laws; intellectual property laws; finance system, multinational corporations; and public and private research establishments. Second, the effectiveness of innovation within a nation is heavily influenced by the efficiency of knowledge flows across these different institutions. Finally, the nature of these institutions differs substantially across each country, so that each national system is in many ways unique, reflecting different cultural, economic and political histories (Freeman 1998).

3. Two other fields of study are relevant. Economic history provides rich material on the role of the 'artisan' in technical progress (Landes 1972; Lazonick 2006). Hall's (1994) classic work specifically focuses on the 'complementarities' between scientists and artisans in the industrial and scientific revolutions. This literature is not dealt with here as the focus is on contemporary studies. The other is more difficult to classify but was influential in industry policy debates in Australia in the 1980s. It argued that to realise the full productive and creative potential of programmable production systems, such as CAD/CAM, required a shift from Fordist work organisation to forms of worker democracy (Mathews 1989). This work is relevant and important given its focus on the central role of trades and techncians in these production systems.
4. A related argument is the systematic link between product and technology cycles and changes in the demand for skills. There are many examples in industries as diverse as chemicals, electronics and atomic power, where initial production required highly qualified experts with advanced degrees. As the behaviour and properties of a production process and product become well-understood and standardised less formally qualified labour is substituted (Kim 2002: 101).
5. More detail on the implications of these surveys for the pattern of innovation and workforce skills is provided in Toner (2009: 23–32; 2011).
6. This list of verbs to describe the activities of tradespeople and technicians can also be found in many relevant Training Packages such as those for metal, electrical and communication occupations.
7. There is not the space to detail this vast and complex public and private system. An excellent description is provided in NCVER (2007). Harris (et al. 2006) is one of the few studies of the private VET system. It is important to note however, that the previous clear demarcation between VET and Higher Education is becoming blurred as some TAFE institutions offer degrees and more universities are conferring vocationally oriented qualifications below the level of degrees. This has led to calls for all post-school education and training to be viewed and governed as a single 'tertiary education system' (Skills Australia 2010).
8. Similar criticism was made by TAFE Directors Australia (2009).
9. The Australian system of vocational education, especially at a trade and technician level, is arguably closer in its key features to the European than the UK model (Toner 2008). The attempt to emulate the UK Competency Based Training model over the last two decades has been tenaciously resisted by some key figures in the local VET system and has been subject to significant academic criticism (Guthrie 2009).

10. For example, Greinert (2007) explains that the ideological foundations of the German apprenticeship system are to be found in the Bismarckian era where it was conceived as a means of protecting the petty bourgeoisie against 'proletarianisation'. Combining general education with vocational training was seen as essential to nation building, especially amongst the petty bourgeois and working class. For the lower classes the concept of *berufliche Identität* (vocational identity) was to be the key to socialisation as *Bildung* was for the bourgeoisie and ruling class.
11. Over the last decade this has changed as UK government 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).
12. During the 1990s capital per worker in the UK was around one-third lower than in Germany and the US. The stock of human capital in the UK 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).
13. An important variation on this approach examines the links between cross-country differences in the innovation intensity of exports and differences in workforce skill compositions (Oulton 1996; Crouch et al. 1999).
14. This literature is closely aligned with the 'Varieties of Capitalism' studies.
15. Taylor's (2004: 625) analysis did not contradict the standard typology; rather it showed that 'the existing evidence depends heavily on the inclusion of a major outlier, the United States' to establish that 'liberal-market economies' are more likely to engage in radical innovation.

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