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Editorial: Adult Learning, Adult Skills and Innovation

Richard Desjardins, Thomas Lans & Peer Ederer

A broader link between adult education and innovation has been highlighted by a number of scholars and analysts in recent years. Overall, a strong correlation can be observed at the country level between adult education activity as measured in the EU Adult Education Survey and innovation performance (CEDEFOP, 2012). Tellingly, this correlation is found to be stronger than that between the proportion of higher education graduates and innovation performance. One interpretation of these data is that tertiary education itself is not sufficient for innovation. That is, higher learning may need to be complemented with adult education, including training and workplace learning, in order for it to make a significant contribution to innovation. Moreover, innovation is not just something that highly-educated people do or something that happens only as a consequence of specialised researchers working in R&D departments. It involves workers across the skill spectrum.

The idea that continuous learning is part and parcel of innovation processes is intuitive. Yet, many policy makers, scholars, and practitioners, such as human resource managers fail to grasp the need to develop and nurture broad-based adult learning systems at the country, regional or organisational level. Is adult learning in all its forms strategically fostered to enable innovation? Can it be or should it be? It is easy to see that these questions have important implications for the EU agenda on innovation. Not least, innovation and entrepreneurship are considered to be key for the creation, development, growth and long-term survival of firms. European statistics are indicative here, as they show that 72% of the European companies have introduced at least one innovation in their company over the period 2012-2015. These innovations occur in a wide range of domains: new or significantly improved services (45%), goods (42%), organisational methods (38%), processes (32%) or marketing strategies (32%) (Innobarometer, 2015).

The topic of innovation and entrepreneurship is important because it is directly relevant for outcomes, such as a start-up or the introduction of a new product, process, practice or service. But scholars increasingly acknowledge that innovation is not just about outcomes, it involves processes of learning and communication. Yet, in practice, it continues to often be approached from a narrow perspective. Take, for instance, well-documented proxies for innovation, such as R&D investment and patent data. The notion behind these proxies is that innovation is a result of a linear process in which universities, research institutes and R&D departments are the core players. Knowledge is created by the research institutes and subsequently finds its way into new products and processes – the so-called Science, Technology and Innovation (STI) mode of innovation (Jensen *et al.*, 2007). Based on this view of innovation, one might conclude that the European food industry is not very innovative compared to other European manufacturing industries. However, this perspective neglects the fact that many innovative firms do not perform R&D and that a large proportion of innovations are not patented. The practice of patenting varies widely according to sector, but this does not mean that innovation does not occur in sectors with fewer patents.

To illustrate the dynamics involved, recent research highlights the importance of interactions with suppliers, customers, stakeholders and other forms of multi-stakeholder processes and feedback from the market as key modes of innovation (Arundel *et al.*, 2007). This mode of innovation - the Doing, Using and Interacting (DUI) mode - is of particular importance in low and medium technology sectors (Arundel *et al.*, 2007) and in particular for Small and Medium-sized Enterprises (SMEs) (92% of all European enterprises have less than 10 employees). DUI emphasises the importance of learning and innovation for the whole workforce. It is not something that is exclusive for those active in R&D departments (Toner, 2011). Therefore, firms are increasingly looking for ways to encourage and foster innovative and entrepreneurial behaviour in their employees.

Several aspects related to innovation processes are thought to lead to success, including successful start-ups or the launch of new products (Reid & De Brentani, 2004). Some of these activities include problem finding, idea generation, information collection, joint problem-solving, idea screening and exploration (Ardichvili, Cardozo, & Ray, 2003). From a skill oriented perspective, these activities are closely connected to what is referred to as 21st century skills. It is not a coincidence that key competencies as identified in the European Reference Framework on Life-long Learning include *sense of initiative and entrepreneurship* (EC, 2006).

As evidence mounts that such skills are subject to learning and development, it is easy to see that the level of commitment to learning that is espoused by organisations is likely to have consequences. Several researchers seem to agree that innovation and human capital are interdependent and reinforce each other (CEDEFOP, 2012; Lundvall & Lorentz, 2012). However, more in-depth interdisciplinary research is necessary, as this relationship seems to be more subtle than often claimed in research and policy reports (CEDEFOP, 2012; Toner, 2011). As Jones and Grimshaw (2012) stated, the conceptual interest in human capital in the innovation literature stays at a rather implicit, superficial level. To be sure, knowledge on learning for innovation and entrepreneurship remains highly fragmented. One reason for this is that it has been studied through different disciplinary and conceptual lenses (e.g. economics, management or psychology), as well as at different levels – individual, group, organisational, and even inter-organisational.

Disentangling the relationships between learning and innovation at different levels is not only relevant for those interested in adult learning, organisational learning, and human resource development, but also for those interested in formal education. For example, highly innovative companies indicate that the organised training of staff in innovation-related aspects such as sales and marketing would be the most important type of public support they could obtain (Innobarometer, 2015). Moreover, initial levels of formal education are increasingly expected to prepare students to self-direct their learning beyond formal education, including on their job. In all sorts of new configurations such as 'living labs', 'innovation labs' or 'hybrid learning configurations', new partnerships are emerging to address today's innovation challenges. These partnerships typically consist of knowledge producing centres, including (vocational) education institutions, businesses and other organisations that aim to develop innovative solutions. Thus, rather than being consumers of innovative knowledge at the end of the innovation cycle, students and teachers become active participants in the innovation process (Wals, Lans & Kupper, 2011).

This special issue has sought to broadly address the theme of adult learning, adult skills and innovation by collecting contributions which draw on analytical insights from a number of recent and ongoing cross-national research projects in Europe that revolve around this theme. These projects include the recent survey conducted under the auspices of the OECD, namely the Survey of Adult Skills (alternatively known as the Programme for the International Assessment of Adult Competencies – (PIAAC)), the EU-sponsored LLLightinEurope project, and the BRAIN (Barriers and drivers regarding adult education, skills acquisition and innovative activity) project sponsored by the Research Council of Norway.

In this Issue

Following the success of the Journal's inclusion of more personal reflection pieces (*thought pieces*) in Volume 50, which are written in a freer style and take whatever angle the author chooses in addressing an important but simple question, we have invited one short thought piece addressing the following question: *'what role, if any, does adult learning play in innovation?'* ***Stephan Vincent-Lancrin*** reflects on this question in a way that adds substantially to the issue by offering a broad overview of the relationship between adult learning and innovation. Importantly, he points out the 'reverse causality', namely that innovation itself necessitates adult learning in order to adjust to new ways of doing things or using new technologies.

The first article is by ***Edward Lorenz, Bengt-Aake Lundvall, Erika Kraemer-Mbula, and Palle Rasmussen*** who base their analysis on PIAAC data to address the relationship between forms of employee learning and work organisation, as well as the role of national systems of education and training. They emphasise the short-comings of a 'skill-deficit' type of thinking, which is still prominent in the policy debate. In highlighting the workplace as an important site for learning and developing expertise, their analysis points to some of the conditions under which national education and training systems can relate to a favourable environment for continuous learning and adaptation.

Moving towards the individual level, the article by ***Liv Anne Støren*** attempts to capture what it means to be innovative. Based on a selection of countries from the PIAAC database, she concludes that the likelihood of 'being an innovative strategic learner' at work is not just a matter of human capital in itself (e.g. education), but is also very much dependent on how work is organised, particularly in terms of flexibility and autonomy. Although from a different angle, namely that of entrepreneurial behaviour of employees, ***Yvette Baggen, Thomas Lans, Harm J. A. Biemans, Jarl Kampen, and Martin Mulder*** confirm the importance of innovative work behaviour at the individual level in their study of SMEs. In their analysis, they go one step further and illustrate that innovative work behaviour is in fact the most important predictor for translating ideas into new projects within companies.

Two other articles focus more on the question of how firms (can) actually foster learning that is connected to innovation. This brings the role of Human Resource Management (HRM) to the forefront. ***Dorothy Sutherland Olsen's*** study of large Norwegian firms illustrates the informal and unplanned nature of learning that is connected to innovation, but also the importance of learning from others within and outside the firm. ***Brandi and Iannone*** further structure the role of HRM by providing an overview of the literature and introducing a model in which they emphasise three aspects of learning strategies in high-performing enterprises.

These include skills development, learning systems and incentives, as well as work design and the organisation of work. They stress the importance of the latter in their analysis of the data they collected from a group of companies.

Finally, an important recurrent topic across all the articles which link learning, work (organisation) and innovation is complex problem-solving. The article by ***Peer Ederer, Alexander Patt, and Samuel Greiff*** delves deeper into the relevance of problem-solving for innovation and taps into a fundamental question: can complex problem-solving skills be developed?

Part II of this issue begins with an article by Jon Olaskoaga-Larrauri, Miren Barrenetxea-Ayesta, Antonio Cardona-Rodríguez, Juan José Mijangos-Del Campo and Marta Barandiaran-Galdós, Between Efficiency And Transformation: The Opinion Of Deans On The Meaning Of Quality In Higher Education.The literature on quality management at higher education institutions has for some time been working on the basis of two issues: a) the diversity of ideas as to what 'quality' means and b) the idea that this diversity is in some way a response to the different positions occupied by stakeholders in regard to the processes and institutions of the sector. It has been suggested that students, employers, administrations in charge of funding and academics may hold different positions concerning the purposes of universities and, therefore, concerning the criteria on which their quality should be assessed. However, those stakeholders have rarely been asked directly what concept of quality they defend. This article presents the results of a survey of deans of Spanish university faculties and schools in which this question was put to them. Their answers contrast with some of the commonplaces of current literature.

The second article, The road travelled in Europe towards the 2020 European objectives in Education. A Spanish perspective, by María Luz Martínez Seijo and Juan Carlos Torrego Seijo, analyses the facts and difficulties that influence the educational policy of the EU to reach agreements and the facts that define common work until the year 2020, mainly under the principle of subsidiarity or complementarity. It also discusses the way to work in the different administrative political systems of the EU countries. Another objective is to discuss the role that National Agencies have in the development of European programmes in the different administrative political systems.

The third article, International Influences on Post-Soviet Armenian Education by Shelley Terzian, constructs an analysis of the most recent international influences on Armenian education, illustrating how international standards are driving post-Soviet reform in the Armenian Secondary Schools.

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Complex Problem-Solving Skills and Innovativeness – Evidence From Occupational Testing and Regional Data

Peer Ederer, Alexander Patt & Samuel Greiff

Introduction

In a seminal article by Nelson and Phelps entitled 'Investment in Humans, Technological Diffusion and Economic Growth' and published in the American Economic Review in 1966, it says: 'Production management is a function requiring adaptation to change, and the more educated a manager is, the quicker will he be to introduce new techniques of production. To put this hypothesis simply, 'educated people make good innovators, so that education speeds the process of technological diffusion'. The key insight behind their modelling was that human capital was not merely one more kind of capital input in the production function, but that particular kinds of human capital, namely better education, would raise productivity directly via innovativeness. Hence, they also observed that 'education has a positive payoff only if the technology is always improving' and vice-versa that 'the payoff to increased educational attainment is greater, the more technologically progressive is the economy'.

If Nelson and Phelps were right, then education could count as a direct determinant of total factor productivity (TFP) in the production function. The debate as to what degree the TFP was merely the 'measure of our ignorance' and whether with only better measurement and model specification it could be eliminated from the model (Hulten, 2001) was conducted between Solow, Jorgensen/Griliches and Denison in the 1960s and 1970s. It has not yet been settled, even conceptually. Studies find that growth regressions work better if human capital is used to estimate productivity level, rather than production input (Benhabib &Spiegel, 1994, 2005; Papageorgiou, 2000: 'for the entire panel of 82 countries over a 28-year period we can reject the Cobb-Douglas Specification' and in 2003: 'post-primary education contributes mainly to adoption and innovation of technology'). Nonetheless, to any degree that human capital and labour market researchers might have hoped that better measurements of education and skill achievement could have filled Jorgensen's 'gap of ignorance' in the production function, ever improved streams of data on educational and skill achievement failed to provide this evidence. As a most recent and most comprehensively comparable example of international skill assessments so far, using data from the OECD Program for the International Assessment of Adult Competencies (PIAAC) survey in 2012, Hanushek et al (2013) showed that economic returns to skills were starkly positive, but varied widely worldwide. This clearly suggests that the economic impact of skills, at least as measured by the PIAAC survey, is moderated by a wide variety of other factors in the economy, and thus does not qualify alone as a replacement for manna from heaven.

Instead of debating education at large, this article focuses more narrowly on only one set of skills, which Nelson and Phelps pointed out: the necessity and ability to adapt to change. Ignoring the econometric specification for the sake of conceptual simplicity, we claim the following steps:

i. Increase in productivity can only derive from innovation
ii. Such innovation causes change to the work force involved in the production process
iii. The adaptation to this change is a process of learning and solving the new environment
iv. This particular process of learning is a set of problem solving skills.

Complex Problem-solving Skills: the skills that drive and enable innovation and change

The fourth step was already announced by Kenneth Arrow in his seminal paper in 1962 on 'The Economic Implications of Learning by Doing'. 'There are sharp differences of opinion about the processes of learning. But one empirical generalization is so clear that all schools of thought must accept it, although they interpret it in different fashions: Learning is the product of experience. Learning can only take place through the attempt to solve a problem and therefore only takes place during activity'. Arrow distinguished this problem-solving learning in contrast to learning by repetition. For this article, we chose a more specific definition of problem-solving skills, the Complex Problem-Solving Skills (CPS). The second and third links are based on Nelson and Phelps, assuming that with higher education they implied that a better educated man would be quicker to learn (adapt) and therefore quicker to introduce the new.

Regarding the first step: ever more detailed data on innovation activity in firms are shining light on the relationship between innovation and productivity growth (Griliches, 1994, 1996, 1998). Research has linked various proxies for innovativeness such as research and development (R&D) spending, rates of new product introduction, comprehensive definitions of innovation spending including training costs and others, as well as various surveys with qualitative indicators (e.g. from the EU Community Innovation Survey) to higher levels of productivity (Hall, 2011; Mohnen & Hall, 2013 for an overview on the relationship between innovation and productivity).

Despite the fact that it would be hard to think of another way in which productivity could increase without innovation of one sort or the other, and the fact that this link has been broadly proven, Bronwyn Hall (2014) declares: 'The full set of links between innovation, competition, exit/entry and productivity growth is not yet explored'. A particular puzzle of this link between innovation investments and productivity growth is why there is not more of such investments. Findings suggest that managers and companies may not invest enough in innovativeness in its various kinds (product, process, business model innovations). Knott (2012) showed that large corporations systematically underinvested in R&D despite its supposed benefits. The OECD (2010) finds the same for small and medium-sized enterprises.

The core hypothesis of this article suggests a shortage of CPS skills in the work force as one of the main reasons why there are not more innovation investments. It derives from Kenneth Arrow's observation mentioned above that a key resource of the innovation process is the problem-solving skills of all the work force involved in the production process. If such skills are not spread widely enough in the work force of a firm (or in a sector or a region), then innovation investments become too risky, even if the rate of return of the innovation seems positive (in this scenario, it can look positive only if the constraint of shortage of CPS skills is not considered). Vice-versa, if the skills can be increased amongst the work force, then, all things being equal, the rate of innovativeness can be increased proportionally to it, and with it productivity.

Absence of such CPS skills will impose a cost on the innovation investment and thus hinder it in the following way: The incentive to finance innovation is to achieve a positive rate of return to the investor. But the process of innovation is associated with initial adjustment costs, which reduce the rate of return to the investor and increase the risks. Such adjustment costs are conditioned by workers abilities to understand and cope with change. The novelty that comes with innovation creates conditions of complexity. Importantly, workers need to understand the impacts and relations of the novelty, as well as the other elements in the system to produce solutions. The longer the workers need to adapt to this complexity (i.e. solve it), the higher are the adjustment costs, and therefore the less likely is the investment to occur. Thus, poor CPS skills may hinder incentives to innovate. In that line of reasoning, we expect that workers with relatively higher CPS skills can attract a wage premium, which is what Ederer et al found in 2015.

This article also considers how job complexity and CPS could interact iteratively to provide a learning environment in which innovation succeeds. This should then be observable in higher rates of productivity and ultimately income. We build on the work of Nedelkoska, Patt, and Ederer (2015) to identify the degree of job complexity in different occupations. First, we test the relevance of the relation between job complexity and income by considering the aggregated mix of job complexity and GDP per capita across regions in Europe. Secondly, we consider the relation between job complexity and CPS skills in terms of a learning process. Finally, we discuss the policy and practical implications.

Assessing the Relation between Job Complexity and GDP at the Regional Level

Several in-depth surveys ask workers about the tasks that they perform in their occupations. As an example, the German Berufsinstitut für Berufsbildung (www.bibb.de/en/14781.php) tasks survey is a representative labour force cross-sections on qualification and working conditions in Germany, each covering between 20,000 and 35,000 individuals. It measures qualifications, career history, and detailed job characteristics in the German labour force (BIBB, 2016). As per Nedelkoska et al (2015), the index of complexity per occupation is constructed using a principal component analysis of responses to the questions of how often workers perform the following tasks:

- collect, investigate, and document data
- have to react to unexpected problems and resolve these
- have to make difficult decisions independently and without instructions
- have to recognise and close own knowledge gaps
- are faced with new tasks, which they first have to understand and become acquainted with

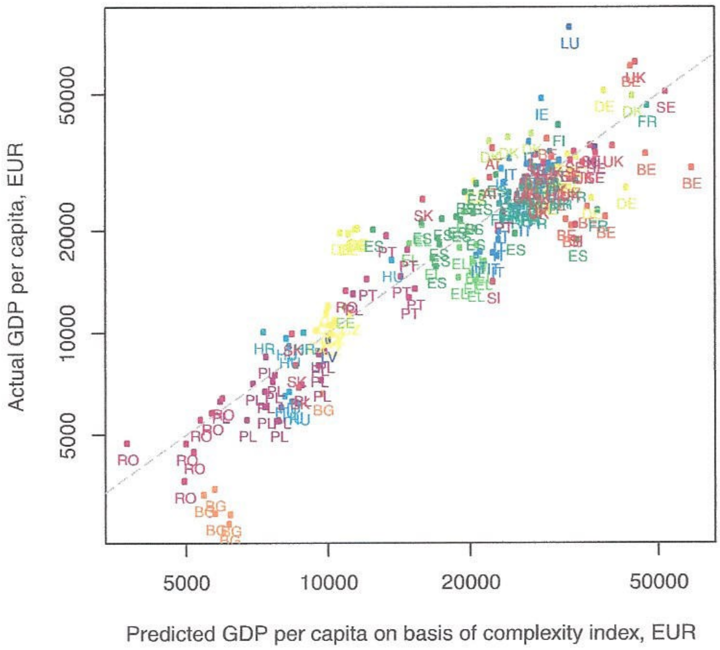

FIGURE 1. Predictive power of job complexity for regional GDP per capita for 197 European regions.
Source: Authors calculations. y axis: Eurostat regional statistics for Gross domestic product at NUTS 2 regions (2007), x-axis: predicted GDP per capita based on complexity index. Complexity index is calculated with data from European Labour Force Survey on occupational composition (2007), German BIBB for the calculation of job complexity scores for 2011/2012. Weighted correlation coefficient in logs is 0.76. Includes one dummy for regions from ex-soviet bloc. Each dot represents one region, each color represents one country. Eurostat country abbreviations are used. (post-crisis level data are not yet available, therefore we used the year 2007 as the last year that is not distorted by the financial crisis

- have to improve processes or try out something new
- have to keep an eye on many different processes at the same time.

This analysis yields a complexity index number for all 2-digit International Standard Classification of Occupations (ISCO) according to the International Labor Organisation classification. These are the same occupational titles that are used in the European Union Labour Force Survey (LFS). Aggregating results at the regional level for 197 Europeans regions, which we can identify in the LFS, we find that average job complexity of employees and income per capita are strongly related at the regional level (Fig. 1). This suggests that regions that have a mix of occupations that is more complex, on average, are more prosperous and have a more productive labour force. The relation is found to have regional implications. For example, there is substantial unevenness in the spatial distribution of job complexity both between and within countries (Figure 2).

The single construct of job complexity index that we created can explain 89% of all variance of GDP per capita across 197 regions in Europe, ranging from Southern Portugal to Northern Sweden, conditional only on one dummy of whether a region

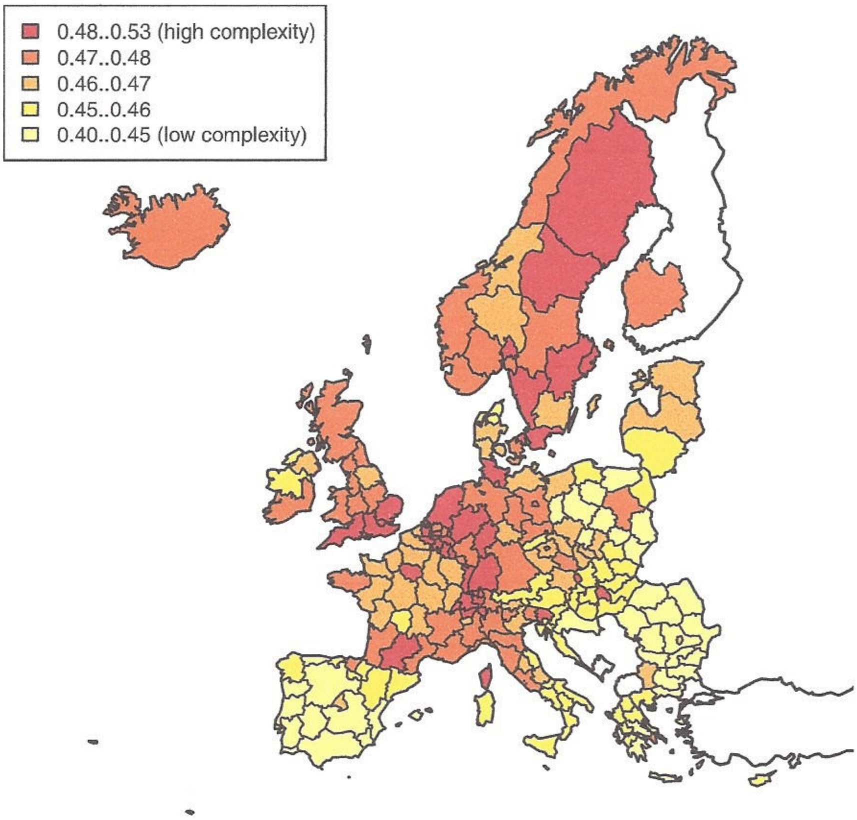

FIGURE 2. Average job complexity by region of the EU.
Source: Authors calculations. Complexity index is calculated with data from EU LFS on occupational composition on regional NUTS 2 level (2007), German BIBB for the calculation of job complexity scores for 2011/2012. The higher the index number, the more complex is the job content of all jobs held in the region.

used to belong to the Soviet bloc 26 years ago. This metric by itself does not explain causality: does a work force first face high levels of complexity and therefore become wealthy, or is a region first wealthy and therefore becomes complex? We argue that asking for causality in this relation hides the actual mechanism of wealth creation. We argue that the answer is causality in both directions, where wealth creation and job complexity are linked via an on-going, iterative learning process in the work force. As the work force is faced with high levels of complexity, it has the opportunity to learn, train, and maintain the skill set of complex problem solving and skills become more available and there are more investments in innovation, triggering yet even more complexity. In this model, it would be the iterative nature of the learning process that permits greater innovation, triggering higher levels of productivity and thus higher levels of income. Rather than asking which of the two came first, the real question would be how to install and promote the iterative learning process.

The Role of CPS

There is little reason to believe that complexity in itself is a creator of economic value. If anything, it would prevent economic value creation because it prevents

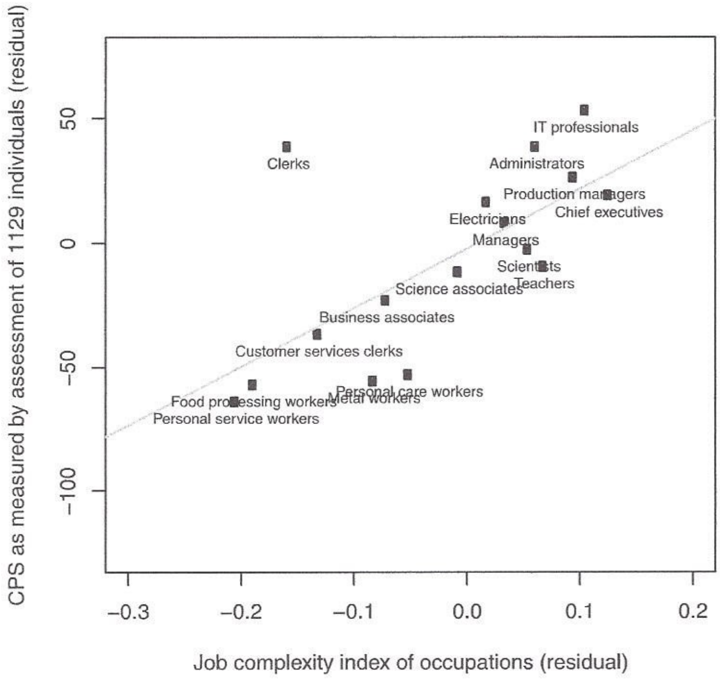

FIGURE 3. The relation between job complexity and CPS skills (residuals after controls).
Source: Authors calculations. y-axis: CPS as measured by authors among 1129 individuals in various occupations and aggregated to ISCO 2-digit level occupational classification. x-axis: job complexity scores as determined from the German BIBB 2011/2012 survey Both CPS and job complexity values are residuals after controlling for age, gender and country of the assessment. The sample is restricted to 18-55 years old. The correlation coefficient is 0.64, which is significant at 1%.

economies of scale from unfolding. Rather, the presence of greater job complexity could be a symptom for higher rates of change resulting from higher rates of innovation leading to greater productivity in the region. However, this innovation can only succeed if the work force can manage and solve this complexity. So the question is, are the higher rates of job complexity also matched by higher rates of complex problem skills? To answer this question, we measured the complex problem-solving skills of holders of different occupations in different countries.

According to Buchner (Frensch & Funke, 1995), CPS describes the set of skills that allows individuals to explore a dynamically changing and obscure system in a way that its structure is understood and can be controlled and orientated towards a desired goal. There are two conceptual aspects of complex problem-solving: a) knowledge acquisition and b) knowledge application. Knowledge acquisition describes the process of constructing a mental representation of a new problem situation through targeted exploration of the problem environment (Mayer & Wittrock, 2006). Knowledge application describes the process of actively intervening into such a system in a way that it moves towards a desired goal (Novick & Bassok, 2005).

CPS skills rely on a number of additional features that require complex cognitive processing, such as multistep planning processes or incorporating feedback in a problem environment that changes by itself and lacks transparency (Wüstenberg, Greiff, & Funke, 2012). In addition, non-cognitive skills, such as self-regulation and need for cognition, are closely involved in complex problem-solving. CPS skills are considered very important for the workplace in the 21st century because they are assumed to equip workers with better capabilities to resolve complexity (Neubert et al., 2015). For example, the Programme for International Student Assessment (PISA) included complex problem-solving in its 2012 cycle (OECD, 2014). The assessment instruments we used to measure CPS for the results presented here are similar to those that were used in the PISA study. Both were developed on the basis of the MicroDYN- (Greiff, Wüstenberg, & Funke, 2012) and MicroFIN-approach (Neubert et al., 2015). In MicroDYN and MicroFIN, individuals work on a number of different problem environments for a short period each and their performance is then scored according to their ability to acquire knowledge of the problem situation and apply this knowledge. Knowledge acquisition and knowledge application scores are then further collated into overall CPS scores. (Detailed information on the reliability and validity of CPS scores within the MicroDYN- and the MicroFIN-approach are found in Greiff et al. (2012), Neubert et al. (2015), and Wüstenberg et al. (2012)).

In PISA, results indicated that complex problem-solving was markedly different from the three content domains that were measured (maths, reading, and science; OECD, 2014). This indicates that the set of skills involved in complex problem-solving differs to some extent from those needed to solve strongly content-related tasks and that the CPS assessments tapped into somewhat different skills. A number of additional studies have shown that measures of complex problem solving were strong predictors of academic achievement and could even predict school grades beyond established predictors such as general mental ability (e.g. reasoning, working memory; Schweizer, Wüstenberg & Greiff, 2013; Wüstenberg et al., 2012). Danner et al. (2011) showed that measures of complex problem-solving were relevant in the workforce, as they predicted supervisory ratings of job performance beyond general mental ability.

Using the test described above, we measured CPS skills of 1129 individuals in 40 organisations from various educational backgrounds. They were aged between 18 and 70, 824 were employed. 61% were men, and 95% came from Germany, Spain, Netherlands, Italy, South Africa, Argentina, Slovakia, UK, Switzerland, Denmark, and Uruguay, whilst the remaining 5% were from other countries.

Controlling for age of workers, we found a strong correlation between job complexity and CPS. The underlying mechanism is mutually reinforcing and difficult to address empirically in terms of causality. For example, young persons at the beginning of their career with a propensity for complex problem-solving may find jobs where this set of skills is required and rewarded, and while they hold this job, this skill set becomes more refined, and vice-versa.

Overall, the findings of our analysis are intuitive. The prevalence of complex jobs is matched by the capacity of workers to manage and solve complexity. Do we have evidence that this mutually reinforcing cycle can be promoted by training CPS on the job and during adulthood? If CPS cannot be learned, then the implication would be that any given labour force is stuck with a given quantity of CPS, for example from initial education systems. This would imply that the total amount of innovation possible at any given time was fixed. On the other hand, if CPS can be learned, then the rate of increase of innovation and productivity would become tied to the speed at which the total amount of CPS in any given population is being trained.

Can CPS be Taught?

To what degree both intelligence in general, and problem-solving in particular can be taught and learned is a matter of on-going debate amongst educational psychologists. Kirkley (2013), basing himself on Gagne (1985), illustrates how problem-solving learning can be effective. Learners need to train two types of knowledge simultaneously: declarative and procedural knowledge, which would respectively translate into Know-what and Know-how. 'When teaching problem solving, authentic problems in realistic contexts are essential', Kirkley claims. Abstract teaching strategies and methods of problem-solving (procedural knowledge) do not seem to create better problem solvers because, when the time comes to apply these general methods, learners will typically not apply them (De Bono, 1983). Nor does teaching facts, concepts and principles (declarative knowledge) because these alone do not cause learners to express mental models from this knowledge and manipulate these with methodologies for problem resolution. However, learning formats in which both types of knowledge are taught in an interlocked way does create problem-solving skills.

Another dimension where training of cognitive skills that are related to problem-solving is effective is the length and intensity of training exposure. Resnick (1999) shows that several training methods have been developed to teach people particular cognitive skills such as logical deductions, creating and using memory aids or monitoring one's own state of knowledge. 'Most of the training was successful in producing immediate gains in performance, but people typically ceased using the cognitive techniques they had been taught as soon as the specific conditions of training were removed'. However, results from placing learners in demanding, long-term intellectual environments are more encouraging. 'We are seeing, that students who over an extended period of time are treated as if they are intelligent, actually become so'. Resnick concludes that intelligence is the sum of one's habits of mind, rather than a fixed endowment of either nature or early nurture.

In an edited volume on Computer-Based Learning Environments and Problem Solving (1990), de Corte et al brought together a wide variety of scholars on the question of how problem-solving could be learned. It reinforces the above insights that such learning is possible if embedded in context and sustained over a long period. Germine (2015) confirms that cognitive functions can peak quite late in life. The importance of these insights from educational psychologists is that they describe well a typical job situation with high complexity content: by definition, such a job represents a long term challenging environment and the performance of complex jobs almost always requires a great deal of contextual (declarative) knowledge. Thus, it seems that a job with many complex tasks represents the ideal learning environment to learn CPS skills. In labour economics, researchers have related task complexity in occupations to learning-on-the-job and skill accumulation (Yamaguchi, 2012, Nedelkoska, Patt, & Ederer 2015; Jovanovic & Nyarko, 1995, 1996), supplying evidence that this learning environment is indeed used. Hence, we come back full circle to Kenneth Arrow's economies of learning on the job. Arrow observed from studies in aircraft manufacturing that learning by repetition was one necessary element of learning a job because it sped up routines and reduced mistakes over time. In this way, economies of scale can be achieved and productivity increased. However, learning by repetition clearly would have rapidly diminishing returns, so that it could have a short-lived boost of productivity at the most. Productivity increases will stop as soon as all routines are acquired. If this is all there was to learning on the job, then its impact on productivity increases would soon be exhausted. His second type of learning, learning by problem-solving can instead deliver sustained productivity increases. This learning also occurs on the job and its function is to be able to manage innovation. The pool of learning resulting from innovations to be introduced does not become depleted as it does for learning routines. Some 30 to 40 years after Arrow, educational psychologists have confirmed that such a job environment with continuous intellectual challenge and a great deal of contextual embedding was indeed a suitable learning environment for learning by problem-solving. Furthermore, with our investigation, we have confirmed that holders of complex jobs had, on average, greater complex problem-solving skills and that the prevalence of complex jobs was strongly correlated to high degrees of GDP income. We therefore conclude that at least some of these problem-solving skills were acquired or strengthened whilst learning on the job in the course of a career.

In economics, this conclusion would have far-reaching effects. If complex problem-solving can and is learned whilst performing a complex job, then this means that any given labour force is not stuck with a given endowment of problem-solving skills (either genetically inherited or somehow bequeathed during education), but that this endowment can be increased, provided there are suitably challenging working environments. If the stock of problem-solving skills can be increased, then this can lead to more innovation investments because more innovation can be expected to be successful and this will increase productivity and with it wealth creation and income.

All this would confirm the models of Nelson and Phelps for which they lacked the empirical data at the time. Only that it was not 'education' in general that would make a manager more innovative, but the set of skills to solve complex problems, which can be learned in an intellectually challenging environment (which could be a formal education setting or a complex job situation), which, in turn, will make any job holder more innovative, not just managers.

Discussion of Implications for Policy and Practice

Our interpretation of Nelson and Phelps needs to undergo further empirical tests to be solidly verified. As we have shown for the European labour market, we can explain observed differences in GDP per capita in 197 regions encompassing all of Europe with an index of prevalence of job complexity for the year 2007.

We assume that any kind of innovation of any type of technology introduces uncertainties and complexities. It is the capacity of the work force to manage and solve such complexity which will determine the rhythm of introduction of such new innovation, irrespective of educational level or occupational category. What primarily matters is the acquired skill set to solve complexity, not the education received. Routine that follows the introduction of a new technology in which problem solvers solved its complexities and made routine possible will then generate higher incomes through repetitive learning. We believe that when insights from educational psychology are combined with descriptions of occupational content on the job, it emerges that this skill set can and is taught on the job. This would make it a possible angle of intervention to raise productivity and incomes in a labour force. This approach also corresponds to findings in sciences ranging from evolutionary biology to management and economics, where authors find that both the existence of complexity and pathways to resolve it are requirements for innovativeness (Hausmann 2011, Wagner, 2014; Ederer, 2014; Hidalgo 2015).

Insofar as CPS skills may be taught, it is worth investing in them in connection to lifelong learning for three reasons:

a) Independent of the absolute level of economic success of a region or company, this set of skills would accelerate innovativeness and thus improve productivity. It can therefore be a true 'catch-up skill' which helps to close economic and social gaps. With a higher rate of innovativeness, an economically disadvantaged region will not only converge towards economically prosperous regions, but can also surpass them (think of Singapore having overtaken much of Europe). By comparison, investment in highly specialised and valuable skills, e.g. aerospace technology or ICT, will only benefit those regions and companies that are already active in these fields and thus increase the gap. Targeted investment in problem-solving skills and methods should lead to increases in innovativeness, independently of the structure of occupations in the region
b) Since complex problem-solving skills contain elements of strategies and behaviours that can be taught throughout adulthood, this becomes a possible area of intervention for all age groups and for true lifelong learning, which should therefore be able to close social gaps. However, insights from educational psychology informs us that such targeted trainings need to be accompanied by the creation of work environments where such procedural knowledge can be immediately and over long periods interlocked with declarative and contextual knowledge.
c) The strategies and behaviours that enhance CPS performance are not necessarily difficult. It is assumed that relatively simple processing strategies such as VOTAT, OODA (observe, orient, decide act, Boyd & Tremblay, 2015) or rhythm-based resolution frameworks such as Scrum (Sutherland & Schwaber, 1995) can result in much better performance in problem-solving at different levels of cognitive strength. It is therefore likely that relatively small investments in training or work place conditions can result in significant increases in effective innovativeness over time – again, provided that the work environment also presents continuing challenges that make the deployment of such strategies useful.

Recent advances in assessment instruments in psychology have made the level of complex problem- solving competence measurable with reliable tests. Applying these tests to holders of different occupations have shown markedly different levels of such CPS. Thus, insofar as CPS performance is trainable and CPS reduces relevant complexity at the time of innovation introductions, this will reduce investment costs in innovativeness, and thus increase the likelihood of willingness to invest in it – which leads to higher productivity and higher incomes. The existence of this mechanism is also suggested when observing the relationship of the amount of complexity that is encountered by given work forces in EU regions, and their productivity as measured by GDP income per capita.

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