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Citation for final published version:

Antonazzo, Luca, Stroud, Dean and Weinel, Martin 2023. Institutional complementarities and technological transformation: IVET responsiveness to Industry 4.0 - meeting emerging skill needs in the European steel industry. *Economic and Industrial Democracy* 44 (1) , pp. 25-46. 10.1177/0143831X211059227

Publishers page: <https://doi.org/10.1177/0143831X211059227>

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Institutional complementarities and technological transformation: analysing VET responsiveness in the context of Industry 4.0 skills needs and workforce development in the European steel industry

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Abstract: Production and the way work is organized are progressively being transformed by digital technologies. In this paper, we explore the implications of such developments, often termed Industry 4.0, for workers through the lens of skill, and the skill needs developing out of a ‘shift’ in the technologies now being employed within the European steel industry. Specifically, we examine the preparedness of initial vocational training systems to support adaptation to Industry 4.0 and the changes in work and employment that will follow. We address such developments from the point of view of institutional theory, analysing how different institutional architectures influence responses to change.

Keywords: Industry 4.0, adaptation, response, skills formation, varieties of capitalism, steel industry

Introduction

The fourth industrial revolution, referred to within the European context as Industry 4.0, sees manufacturing companies aiming to achieve interconnections of all elements of the value-added process (from raw materials and pre-products, down to logistics and customer feedback), transforming analogue data into digital data (Schroeder, 2016) and using cloud computing and data science to improve efficiency and competitiveness. It is the idea that production can be configured upon digital networking systems and the centrality of ‘big data’ for ‘smart factories’, and argued to carry numerous implications for the organisation, structure and

experience of work (e.g. Briken et al., 2017). However, there is little agreement on the ways in which such developments will impact the future of work, and precisely what the technological transformation will mean for skills, competencies and qualifications (e.g. Autor 2015; Frey and Osborne, 2017; Spencer 2018, Hirsch-Kreinsen et al. 2019; Spöttl and Windelband 2020).

To provide some greater clarity to debates focused on the skill and training implications of Industry 4.0, we discuss the response of vocational education and training (VET) systems, as a central plank of skill formation, to technologically driven change and emerging skill needs in one sector. Based on the findings of a large European steel industry project, we address in comparative ways the response of different Initial-VET (IVET) systems to the new skills requirements and learning arrangements (as identified by company personnel) arising from the 4.0 transition. We do so from the point of view of institutional analysis, drawing on the institutional complementarities literature (Amable, 2000; Amable and Petit, 2001; Hall and Soskice, 2001). IVET is defined as “vocational education and training carried out in the initial education system, usually before entering working life”, but the concept of IVET does not necessarily entail a specific education level or training arrangement (e.g. school-based or apprenticeship based), i.e. it can also apply to re-skilling, if aimed at reinsertion into the labour market (see Cedefop, 2014: 117).

We analyse IVET systems in Germany, Italy and the United Kingdom and ask how they have responded to the skills challenges posed by Industry 4.0 – and the steel industry particularly, focusing on the production and maintenance skill needs discussed by steel sector stakeholders in each of the aforementioned countries. Specifically, we intend to show how the institutional architecture of a country influences the type of response more likely to be put in place in the face of external pressures, and how different types of responses tend to be associated with different levels of institutional hybridisation. By hybridisation we refer to ‘the process through

which tentatively imported institutions are transformed via their interaction with domestic institutional forms' (Crouch et al., 2005: 368). To assess different types of responses, we will introduce a model combining two analytical dimensions, mediation and optimisation, to distinguish between what we define *adaptive and impulsive responses* (AIR), and reflect on their consequences. With this model, we intend to complement the institutionalist literature with a conceptual devise that adds extra analytical dimensions to the study of institutional change and links the premises and outcomes of institutional reforms. Finally, we offer a contribution to the debate on the opportunities and challenges brought by Industry 4.0, showing how different types of responses in the domain of IVET address the transition to a new work scenario, their potential limits and the implications for (future) production and maintenance workers.

In the next section, we discuss the theoretical background of the paper, introducing the institutional complementarity hypothesis as a key concept within the comparative capitalism (CC) research programme, and our definition of adaptive and impulsive response (AIR). We then briefly discuss the project that provides the data for the paper and the research design. Subsequently we analyse the effects of Industry 4.0 on skills requirements, focusing on the case of the European steel industry. Finally, we present how the three case study countries are responding to the changing skills requirements in terms of IVET reforms and we discuss the effectiveness of these in supporting future workforce development and the 4.0 transition of the industry in the light of the institutional complementarities approach.

Theoretical background

The assumption behind the idea of institutional complementarities is that a society's institutions are shaped by their historical path and that these, once considered in their joint combination, make up coherent models, which can differ deeply from one country or macro-region (e.g. Scandinavian models, continental Europe models, etc.) to another. Most importantly, the different models influence the processes that occur within their societal domain, generating specific trajectories, outcomes and performances i.e. path dependence (Evans and Stroud, 2014). This notion is at the core of influential institutionalist research programmes, such as Varieties of Capitalism (VoC) (Hall and Soskice, 2001), and provides important insights on the functioning of different economic and production systems and the effectiveness of structural reforms.

Hall and Soskice's (2001) VoC approach distinguishes between Liberal Market Economies (LME) and Coordinated Market Economies (CME). The first, best embodied by the United States and the United Kingdom, is characterized by the primary role of the market in regulating the economic system's dynamics. This leads to short-term strategies based on high returns and short payback and low trust between firms, and between firms and institutional actors. CMEs, usually represented by Germany, are characterized instead by higher state intervention that regulates economic dynamics within the market. Here firms are strongly linked through sectoral associations and with the relevant social partners. Companies are encouraged to adopt more long-term strategies and are less dependent on financial markets.

From a skills perspective, VoC analysts point out that CME employment protections and coordinated wage bargaining institutions encourage workers to commit to a lifelong career and to develop specialised skills, while in LMEs the absence of such safeguarding institutions pushes workers to invest in general (i.e. highly portable) skills to reduce the risk of unemployment. On the other hand, companies tend to adapt their product market strategies to

the pool of skills available to maximise their competitive edge, producing self-reinforcing mechanisms. While LME firms have an incentive to rely less on technologies that require specific skills, increasing the demand for general skills, companies located in CMEs engage more in production that requires skilled labour, considering the large availability of this, thus reducing the opportunities for workers possessing only general skills (see, for example, Estevez-Abe et al., 2001).

Several scholars have worked on enlarging the comparative capitalism analytical framework. Amabel (2003, 2009) offers a more nuanced typology which considers, besides the market-based and the continental European model (akin to LMEs and CMEs), also Mediterranean capitalist countries, like Italy and Spain, social-democratic capitalism, typical of Scandinavian countries, and Asian capitalism. For the aims of this paper, we refer to Mediterranean capitalism (to discuss Italy), in addition to LMEs (to discuss the UK) and CMEs (to discuss Germany). Mediterranean capitalism is described as based on more employment protection and less social protection than CMEs. It relies on “a large set of family-based small firms, cross-participation in firms’ governance and the prominent role of the state in the economy” (Vallejo-Peña and Giachi, 2018: 24). It is also characterized by a relatively low level of market competition and by a workforce with limited skills and level of education, which does not allow for the implementation of a high-skills/high-wages industrial strategy (Amable, 2003).

An important theme of debate in institutional analysis concerns the degree of fit between different institutions. The pre-assumption of the original VoC model, is that institutions fit tightly (Amable, 2016), which would imply that any attempt at reform or hybridisation would cause a negative feedback loop dissolving the stability and coherence of the model and its comparative advantages. But, what is found is that whilst ‘neoliberal structural reforms have been implemented for at least three decades... [the]... diversity of capitalism persists, even if

less pronounced than it has been' (Amable, 2016: 89). For example, Germany, as the best illustration of a CME, has in recent years experienced similar transformations to its labour market as elsewhere in Europe [i.e. some convergence], but 'the adjustment trajectory of the German political economy... [is noted to entail]... continued co-ordination *and* liberalisation' (Hassel, 2012: 75. *Our emphasis*).

Where policy reforms are attempted (e.g. on skill formation systems), scholars in the VoC tradition have maintained that these can positively impact on economic performance only where they combine with pre-existing coherent institutions (Hall and Gingerich, 2009). Others note however, that in certain cases mixed institutional forms can complement each other well and perform effectively on a systemic level (Campbell and Pedersen, 2007). But, institutional transplant and hybridisation may fall short of stakeholders' expectations, as noted by Nölke (2019), for example, on the failed 'institutional transplant' of some components of the German training model to other countries. What the idea of hybridisation conveys is the opportunities and risks for the evolution of institutional architectures. Indeed, Boyer (2005) highlights that hybridisation is one of the mechanisms that potentially drives institutional change, both in terms of destruction of obsolete configurations and creation of new institutions and complementarities. On the one hand, it implies that 'there are some degrees of freedom within each institutional form' (Boyer, 2005: 70), but equally, as noted, there is the danger that imported institutional forms might not produce the expected outcomes (e.g. Nölke, 2019).

Seminal studies (e.g. Thelen, 2004) underline that the relationship between institutional reproduction and institutional change is far from linear and that there are many possible avenues for institutional innovation. Our aim is to reflect on the circular relationship that can be identified between a) institutional architectures and underpinning complementarities, b) types of responses that stem from such architectures (e.g. institutional reforms in VET), c)

effects of hybridisation (e.g. its capacity to establish new complementarities or clash with pre-existing ones). In our framework, the concept of response plays an important role as it links premises to outcomes.

Should Industry 4.0 demand new skills, competencies and qualifications, as many have argued (see, for example, Stroud and Weinel's (2020) discussion of digitised drones), and as we will show in what follows, skill formation systems – and IVET systems specifically – must offer a response. By *response* we mean any type of reaction to a new situation or scenario. We thus centralise the fact that responses to a common challenge can vary, giving rise to a variety of response types. While 'response' can be characterised in a variety of ways we do not aim to develop an exhaustive classification but focus our analysis on a distinction between *adaptive* and *impulsive responses* (AIR). Our distinction is based on considering two different dimensions that we refer to as mediation and optimisation:

1. *Mediation* represents the will or capacity of governments to translate exogenous pressures into a national agenda, selecting a response strategy among many possible through negotiating this with stakeholders and social partners. It is based on the capacity to proactively anticipate potential changes and challenges, channelling these into a desired trajectory of societal change.
2. *Optimisation* implies systematic learning, rather than *ad hoc* solutions and represents the degree to which problems are confronted building on one's own resources, experience and stock of knowledge, and pre-existing arrangements.

Building on this framework, we define *adaptive response* as a proactive process accomplished through high levels of mediation and high reliance on own resources, experience and stock of knowledge. Conversely, we define *impulsive responses* as characterised by low mediation, low reliance on own resources, experience and pre-existing arrangements, and low proactivity.

The AIR model adds understanding to the dynamics of institutional change, highlighting that the problem of institutional reform needs to be framed in terms of a circular relationship between premise (the pre-existing institutional architecture and complementarities), intervention and outcomes (the reform and its effects e.g. hybridisation and its consequences). In other words, where change is urged by new working conditions/skills demands, we argue that (IVET) reforms that are neither based on pre-existing complementarities, nor capable of establishing new ones, might hybridise the (IVET) ‘system’ in a way that is not effective in meeting the objectives targeted by the reform because of institutional inconsistencies. The concept of AIR works as a link between the pre- and post- reform and sheds light on the likelihood of the reform to meet expectations based on its institutional premises.

In the discussion section of this paper, we will apply this framework to the case study countries, and we will reflect on how different institutional models influence the type of response that countries are more likely to put in place, and the effectiveness of these in addressing the skills gaps produced by Industry 4.0 and supporting future workforce development.

Methodological notes

This paper draws on data from a large and significant Erasmus+ project, which addresses the challenges of the European steel industry in terms of digital skills needs, particularly regarding how the industry is served by IVET and CVET systems in different countries, with the focus of this paper on the former. The steel industry is experiencing significant technological transformation and might act as a proxy to assess the new skills needs derived from Industry 4.0 transformation (Murri et al., 2020). The project has a Europe-wide focus, but for the

purposes of this paper we limit our analysis to Germany, the United Kingdom and Italy. The rationale underpinning our case selection is both empirical and theoretical.

First, each country embodies a different institutional architecture as described in the previous section. In turn, the three institutional models illustrated by the countries are associated with different skills formation systems, as the comparative capitalism literature has shown (Vallejo-Peña and Giachi, 2018; Thelen, 2004; Estevez-Abe, 2001). Second, in relation to our focus on the steel sector, all three countries have a significant steel industry, with Germany and Italy being respectively the largest and second-largest producers in the European Union and the UK being the seventh-largest producer (Eurofer, 2019). Third, in relation to Industry 4.0 enabling technologies (Martinelli et al., 2021), Eurostat data¹ show that they are penetrating companies operating in the manufacture of basic metals and fabricated metal products (thus including the steel industry), including in the three case countries. Fourth, all the case study countries have undergone in the last 15 years relevant reforms in vocational education and training at the upper- and post-secondary level, devised to better align IVET with changing labour market requirements. Some of these reforms will be analysed in the following sections.

To discuss industry developments and IVET reform we use data generated through semi-structured interviews with companies' representatives (HR managers, production managers, training centre managers), VET providers/experts (in-company training centre managers, VET research institute representatives and vocational centres programme managers), and trade unions. The research initially planned as fieldwork had to be re-arranged after the Covid-19 pandemic. Interviews were conducted remotely via telephone, Skype or Zoom and usually

¹ See Eurostat datasets: Key technologies for the internet of things (code: isoc_bde15dt), Big data analysis (code: isoc_eb_bd), 3D printing and robotics (code: isoc_eb_p3d).

lasted between one and two hours. The data informing this paper derives from the early part of the project, which started in 2019 and is ongoing till the end of 2022. The first phase of research focused on the analysis of IVET systems of the case study countries, and this paper draws on a pool of 36 interviews (see *Table 1*), conducted between April and September 2020. The interviews have been used to complement secondary data i.e. desk research on IVET in each country to reconstruct a broader European sectoral perspective on skills needs deriving from the industry transitioning to 4.0 and new IVET arrangements.

Table 1 – Interviewees distribution

	DE	IT	UK
Company representatives	11	4	2
VET experts²	5	4	5
Trade unions	1	2	2

Steel industry 4.0 and emerging skills needs

As Stroud and Weinel (2020: 298) note, the European steel industry has over past decades experienced major processes of restructuring, which has resulted in changes in the character of the workforce: ‘it is now a smaller, differently recruited and organised workforce, more highly skilled and qualified than once was the case’. The expectation is also for a workforce that can adapt to sector innovations, with the latter primarily focused on decarbonisation and improving production efficiency for greater competitiveness in a global market (Evans and Stroud, 2014).

² This category includes in-company training centre managers, VET research institutes representatives and vocational centres programme managers.

Of late, Industry 4.0 has been argued to carry the greatest innovation potential for the sector (Murri et al., 2020), and with it the possibility of a ‘business model transformation’ (Naujok and Stamm, 2017). There is, indeed, evidence of Industry 4.0 penetration across the sector (Murri et al., 2020), but its extent differs to some degree from site to site, company to company, country to country (White Research et al. 2020). We acknowledge this unevenness, but in what follows our aim is to sketch out the more general trends with regard to Industry 4.0 across the sector, and the implications for skills, as evidenced by our cases. Our level of disaggregation by case, as will be discussed in later sections, is in the IVET reforms/response to this particular picture of technological transformation across the sector and the emerging skill needs.

What we note is that the European steel industry is progressively moving towards Industry 4.0 with firms starting to make use of IoT models, sensors and big data analytics to improve energy efficiency and resource management, as well as quality monitoring and defects detection (see Murri et al., 2020). Robot-assisted production is increasingly allowing workers to supervise, instead of performing, dangerous and labour-intensive processes and tasks. Such developments and associated skills needs are confirmed by our interviewees. A senior production manager at an Italian steelworks sees I4.0 technology’s most relevant application as enhancing the reliability of machines and processes, through the constant acquisition of data from each component. Similarly, the Head of a company training centre in a German steelworks underlines the advantage that extensive generation, storage and analysis of data will give to companies to act and improve processes, or plan a recurring intervention on machinery based on sensor data and computer simulation.

Although the steel industry might not be at the forefront of the Industry 4.0 revolution (compared to automotive, for example) and developments are unevenly distributed, expectations concerning future competence and skills requirements resurface repeatedly in

steel-sector specific research (Stroud and Weinel, 2020; White Research et al., 2020) and in our interviews with company and unions' representatives. Indeed, as a sector case, our interviews have mainly focused on the changes potentially affecting production line and maintenance workers, and the foreseeable skills and vocational training challenges that those preparing to work in such roles are likely to face.

Besides technical skills and knowledge, strictly related to the steelmaking process and to the functioning and maintenance of machinery and devices (depending on the role of the worker), a common trait is the increased importance placed on process or systems knowledge, which stems from the increasingly integrated or networked character of production processes and the use of digital technologies that render processes more invisible and harder to grasp (Zinke, 2019: 73):

“The demand for professional profiles that are able to master, or at least know much better than before, the entire production process [...] has intensified” (Trade Union representative, Italy).

[W]ell we have done surveys within our company and there is one core message coming from this: ensure that apprentices have a contextualised understanding and understand the plausibility what is happening. [...] We offer programmable logic controller (PLC) for metalworkers. Normally metal workers will not learn PLC, it's not their world, nonetheless, we have been asked to please introduce metal workers to PLC so that they will understand what electricians are actually doing and so that they can talk about it [...] The point is not to educate them deeply in these areas. Rather, the point is that they have what I call 'overview knowledge' (Training centre manager, Germany).

Related to this is the importance placed on cross-boundaries communication within a modern company:

You have to make sure that the electrician knows what the electronics do and that the electronics know what the electrician does and change these kind of boundaries (Automation manager, Italy)

The subject-specific knowledge itself does not do anything. [...] I really need the knowledge that allows me to reach into different areas. As an engineer I need to see how I manage working together with IT people or admin staff or I am a mechanic but have to understand some electrics. I do not have to know everything, but the connectivity between people with different backgrounds helps immensely. (Training centre manager, Germany)

The increased importance of personal and social competences, often referred to as soft skills, is another recurrent theme in our interviews data. Good communication skills, assertiveness, leadership, teamwork, are highly valued in the modern steel company:

What young people lack often is soft skills [...] they lack leadership skills a little [...] they are very afraid to step forward, to show themselves. So we work a lot on this, we encourage them to ask questions, to show themselves, to present their ideas (HR manager, Italy).

“decision-making process and problem solving are always a key thing for us. And I think the two go sort of coupled [...] Especially with the structures we have now, a lot flatter. The teams are more flexible, but we are still trying to push on the decision takers within those teams” (Training advisor in steel company, United Kingdom).

A common assertion in the literature is that soft skills will be required across the whole spectrum of workers, from low-skilled to specialised (Lloyd and Payne, 2002). This attitude seems to be supported by most of our interviewees, but an apprenticeship manager in the UK maintains the idea that soft skills relate more to higher-end roles, such as engineers and mentors, rather than apprentices:

[apprentices] get teamwork and communications. Communicating with engineers is one of the BTEC units. And there is also one for teamworking. But other than that, nothing again [...] I'm reasonably happy with how it is, I think perhaps the more experienced...perhaps some of the engineers would potentially benefit from that. And some of the mentors may benefit from that. But we offer coaching and mentoring courses, which, you know, covers softer skills (Apprenticeship manager, UK).

Our interviewees often underlined how the ongoing technological transformation will require a continuous commitment to learning. In the light of this need for continuous updating and

upskilling of workers, personal and social skills play a crucial role, as they provide the grounds for continuous learning:

[...] the core of occupational education is to develop personal and social competences. Because if we have developed those then people are in a good position to acquire other kinds of competences, knowledge and skills on their own. (Head of training, Germany).

Cedefop's Skill Panorama (2019) reports that digital skills will also be of unquestionable importance for metal and machinery workers, and that these need to be constantly updated, in line with technological advancements.

A UK union representative talks about the importance of digital skills for the steel industry but warns about the need to build these on robust foundational skills:

[...] digital skills is massive for me, but also without forgetting that millions of workers in the UK still don't have basic literacy and numeracy skills. So, if they do not have basic literacy, numeracy, how will they have those skills to then be able to replicate it digitally? (Trade union representative, UK).

While there is much focus on entirely new skills and competences that become more prominent due to digitalisation and Industry 4.0, this does not mean that classic job- or occupation-specific technical skills lose importance:

And even in 2030, we will educate apprentices in the basics of sawing, filing and welding and so on, because in the end we need people who can change a pressure roll, who can weld something that needs welding and so on (VET trainer, Germany)

Indeed, the need for foundational and soft skills goes along with the need for more robust technical skills, especially where these incorporate some IT competencies:

[We need more] highly specialized technicians, mechatronics, with bases of computer, mechanics and electronics that are precious on the labour market. It is difficult to find them and when we do, we hold them tight (HR manager, Italy).

Our findings align with research aimed at understanding the skills gaps in the sector (e.g. White Research et al., 2020). Overall, there is a need for higher technical skills, especially in the fields of engineering, material sciences, physics, chemistry and IT, but also soft skills to cope with a fast-changing workplace and to navigate the industrial transformation. Indeed, the need for a more holistic approach to occupational training, requiring workers to have ‘wider and more adaptable skillsets’ (White Research et al., 2020: 12), is remarked upon:

“Until now, much has been built on a mode that was particularly linked to a specialisation model that saw the fragmentation of skills, knowledge and the roles themselves. Recomposing this, also from the point of view of the overall ability to understand the production process, is one of the issues on which there is a stronger demand” (Trade Union representative, Italy)

From this, stems the necessity of adopting a T-shaped (technical and transversal) approach to skills, including ‘an area of speciality complemented with a series of transferable skills, which can be grouped in three overarching categories: general technical skills, digital skills and soft skills’ (White Research et al., 2020: 56).

The transition to 4.0 is an incomplete but ongoing process in most of the researched companies. The skill needs described in this section will be more evident for the future production and maintenance workers entering in a transformed steel industry. IVET will play a crucial role for those workers, addressing emerging skills needs and endogenously building the capacity to meet prospective challenges, in fact bridging the present and the future of the industry. In the next section, we describe some recent IVET reforms that address the skill needs outlined, before discussing the type of responses these represent in the light of the institutional complementarities hypothesis.

IVET reforms in UK, Germany and Italy

IVET systems have increasingly been called upon to address a number of common challenges derived from profound exogenous transformation (economic, technological, demographic) and a need to realign to the labour market, providing more adequate skills and enhance the attractiveness of vocational education (for learners and employers) (Bosch and Charest, 2008). Such challenges and shortcomings have often been tackled through importing recognised ‘best practices’, based on the normative assumption that these could strengthen IVET systems or solve existing or potential problems (Turbin, 2001). This is argued to have resulted in a certain degree of convergence in IVET reforms across the EU as they have responded over the last two decades to the new conditions (Cedefop, 2018).

The most common reform packages have consisted of strengthening the ties between IVET and the labour market (through involving employers more in the design of the qualifications), relaunching apprenticeships to anchor training to actual jobs (some form of ‘duality’), broadening courses contents to equip learners with more transversal skills, and extending and strengthening IVET provision at post-secondary and tertiary level (Cedefop, 2018). These common trends resurface to some degree in recent IVET system reforms in our three case study countries. Our analysis focuses on those reforms that meet the following criteria: a) belong to the IVET segment; b) have a steel industry relevance; c) have a strong focus on digitalisation and I4.0 technologies, and d) have been devised/introduced in the last 15 years (in parallel with the onset of the technological leap).

We start with the UK and the caveat that devolution of responsibility for IVET to the constituent parts of the UK (Wales, Scotland, Northern Ireland and England) makes it difficult to speak about a UK approach to IVET provisions and reforms. Nonetheless, it can be said that the similarities between the systems are greater than the differences despite efforts by the

devolved administrations to move in new directions (e.g. Pring et al., 2009). Typically, the UK IVET system is criticised as fragmented, complex and little more than a silo for less able young people not entering higher education (Bosch and Charest, 2008; Pring et al., 2009). The ‘system’ experiences constant ‘innovation’ and reform and often finds itself the focus of government rhetoric on skills. More recent IVET reforms (Abusland, 2019; Cedefop, 2020) that are partly driven by the Industry 4.0 agenda, include England’s apprenticeship frameworks being replaced by new standards developed by sectoral panels of employers, which are occupation-focused (rather than qualification-led) and combine on-the-job training and study. New standards for metalworkers comprise subject-related theoretical knowledge as well as technical abilities and soft skills such as communication, problem solving and teamworking.

In addition to new standards, the Department for Education started developing in 2017 new technical study programmes called T-levels, aiming to simplify the national (England) IVET system, at the same time as enhancing the credibility of qualifications with employers. T-Levels are intended to be 2-year courses (starting from September 2020), based on the same standards as apprenticeships and will include compulsory elements such as core theory, concepts and skills for an industrial area, alongside specialist skills and knowledge for an occupation or career. Planned T-Levels curricula (to be rolled out systematically in the next two years) such as “engineering, manufacturing, processing and control”, “digital production, design and development”, “digital support services” seem particularly relevant for the future steel industry. Furthermore, the programme will offer students a mix of classroom learning and ‘on-the-job’ training during an industry placement, in so meeting the employers’ requirement for earlier work experience.

In contrast to the UK, the German IVET system is well-known for its solid dual approach and the embeddedness of social partners and stakeholders in its governance. This also means that

recent IVET reforms lack explicit elements designed to improve involvement of employers in the design and more practical orientation of qualifications. The German approach to recent IVET reforms has been incremental rather than structural (Hippach-Schneider and Huismann, 2019; Cedefop, 2020). With regard to steel sector related qualifications, recent changes are oriented towards filling skill and competence gaps, increasing the flexibility and freedom within occupational qualification offers, and improving the permeability of the system to increase re- and up-skilling opportunities, rather than introducing any systemic change. A relevant example of incremental reform that applies to the steel industry is the updating of the curricula of 11 metalworking and electrical qualifications to meet the new industry and market challenges. The training regulations for qualifications such as mechatronics fitter, production technologist, plant mechanic, electronics technician for devices and systems, have been amended and updated with the involvement of the relevant social partners. Moreover, a ‘module’ on the ‘Digitalisation of work, data protection and information security’ (*Digitalisierung der Arbeit, Datenschutz und Informationssicherheit*) has been introduced.

Metalworking occupations have also been updated with training on process integration, system integration, IT-based plant modification and additive manufacturing procedures. As pointed out in an interview with a VET expert in Germany, such modifications were introduced to react flexibly to the unevenly distributed needs of companies. Hence, the additions are not mandatory for apprentices, but they have legally regulated minimal standards that assure quality and transparency across the IVET system. Completion of such elements can also be certified by relevant industrial chambers. More recently, emerging skills gaps related to digitalisation and environmental sustainability have been plugged across all dual apprenticeships by introducing completely new ‘standard modules’ and by updating and modernising existing modules on labour law and collective bargaining as well as on occupational health and safety (BMBF, 2020).

As for Italy, upper secondary and post-secondary IVET programmes were reorganised in 2008 to better target the professional requirements of the labour market (Angotti, 2019; Cedefop, 2020). Upper secondary technical and vocational schools' curricula were rationalised and consolidated reducing the overlap between similar ones and job placements were introduced. Vocational schools' curricula have been updated again in 2017. In the context of school-based vocational and technical programmes, curricula such as “mechanics, mechatronics and energy” and “electronics and electrotechnics” and “ICT” seem to fit well the needs of a steel industry transitioning to intensive automation and digitalisation.

At the post-secondary level, new higher technical training programmes (ITS, *Istruzione Tecnica Superiore*) were established. These must be collectively organized by schools, vocational centres, universities and companies and are designed to have strong ties with the labour market and to keep into account the specific industrial characteristics of the Regions. The ITS curricula, updated again in 2011, are organised in broad subject areas such as “energy efficiency”, “new technologies for made in Italy” and “ICT”. Half of the subjects make use of I4.0 key enabling technologies for learning and training, and job placement is a substantial component of the programme.

Furthermore, a reform in 2015 established the opportunity for learners to obtain a secondary vocational qualification or a diploma in a dual-mode to fill the gap between formal IVET and companies to tackle youth unemployment. Finally, IVET profiles that belong to the strictly vocational route (IeFP, *Istruzione e Formazione Professionale*) have been updated and integrated in 2019 after a two-years review process. This has resulted in revised national standards with strengthened foundational and technical skills, and in the addition of new profiles (e.g., the profiles of digital modelling and production technician, and renewable energy technician seem particularly relevant to the current challenges faced by the steel industry).

Also, the Italian regions have collectively agreed to incorporate personal, social, learning and entrepreneurial competencies to the curricula – ‘soft skills’ identified as a steel sector skills need.

Seemingly, the skill needs emerging from the I4.0 revolution, identified by the literature, but also by interviewed steel sector actors, would appear to be addressed by the reforms presented in this section. Supposedly, IVET programmes are now devised to connect more with companies and incorporate an organic mix of theoretical concepts, technical, digital (including more advanced IT and programming, in some cases) and soft skills. This is now often complemented by practical experiences through job placements or dual arrangements. In the next section, however, we analyse these *responses* in the light of the AIR model outlined earlier, and we discuss their capacity to cope with the challenges posed.

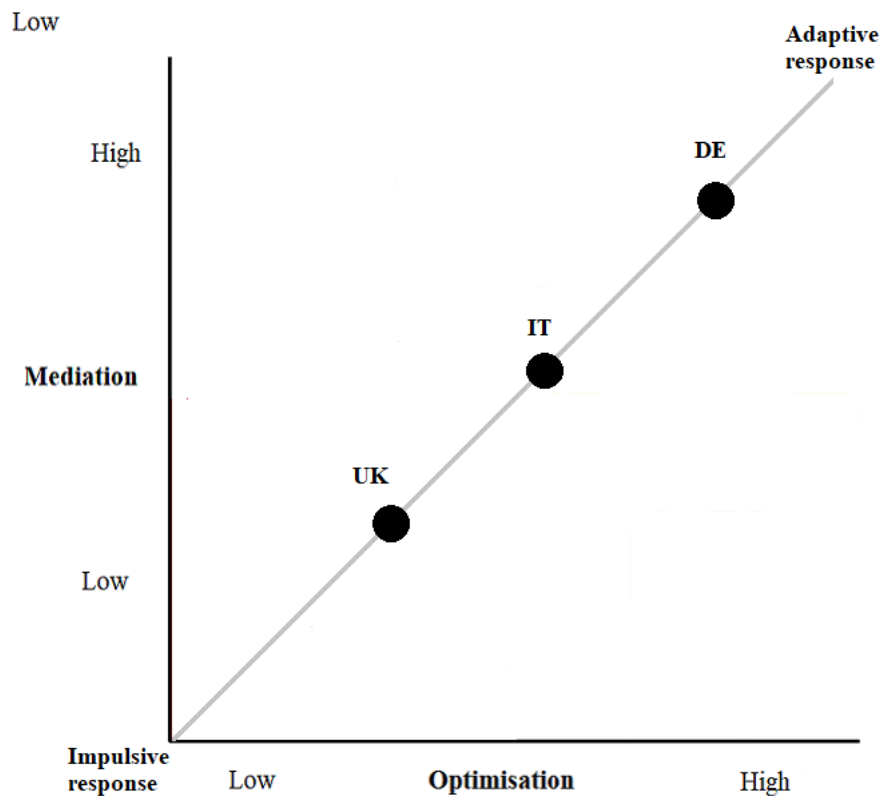
Discussion: response types, hybridisation, and workforce development

In this section we turn our attention to the institutional context in which the respective IVET reforms play out against the background of technological innovation within a sector. We argue that the potential effects of IVET reforms can only be properly assessed when considered in their institutional context.

For our analysis we utilise the AIR framework introduced earlier in the paper, which opens a spectrum of responses ranging from adaptive to impulsive. Graphically, this translates into a bi-dimensional cartesian model, as represented in Figure 1. The X axis represents the optimisation dimension, while the Y axis represents mediation. Both axes range from low to high. The diagonal is the projection of an ideal continuum between the two poles of adaptive and impulsive responses. We also utilise the categories provided by the comparative capitalism

institutional framework to distinguish between institutional architectures in the three case study countries.

Figure 1: AIR Model Case Distribution



Our model aims to illustrate graphically the trends described by the IVET reforms in the three countries. The positioning on the diagonal represents whether national VET systems are gravitating towards the area of adaptive or impulsive responses.

We consider Germany to have put in place reforms guided by progressive optimisation, a proactive strategy, and a high level of mediation. We describe Germany's response (in terms of IVET policies) as essentially *adaptive*. We also maintain that adaptive responses, associated with the typical CME institutional architecture, tend to produce a lower level of hybridisation. The tripartite arrangement typical of a CME, which also structure IVET-related decision-

making, makes it difficult to quickly implement radical changes and to promptly adapt to the new market conditions:

The current system is strongly rooted in the belief that a *Beruf* [occupation] is something very special and also comes with a strongly established system of authorities, responsibilities and hierarchies (Head of training centre, Germany)

This sometimes brings along employer concerns, who might advocate for some degree of hybridisation of the system (e.g. borrowing training practices from other countries) to enhance its flexibility and better cope with the dynamism of the labour market:

In the dual system, I would find it better if we were to look at the English system and consider more modularisation and also stop to differentiate so early' (Head of training centre, Germany)

However, the reforms described show that the German approach still relies mostly on progressive optimisation – the modularisation that has been adopted, as discussed in the previous section, is different in character to that in the UK. Germany's recent reforms are coherent with the institutional complementarities described in the CME model. The 'adaptivity' of German VET with regard to industry 4.0, as shown by the example of the metalworking and electrical qualifications, relies on a circular process of reviewing the curricula and integrating the missing contents and skills. This process is incremental and builds on what is considered by the policymakers to be 'solid grounds'. This type of adaptation is slower in terms of response and less flexible, but avoids the risk of institutional inconsistencies. The principle of co-determination guarantees the complementarity between IVET institutions and industrial relations and is based on a high level of mediation.

The devised strategy of providing additional contents and modules to the existing qualifications is not free from critique:

We know that skilled work changes, that the training profiles lose their fit with what is needed, and the demarcations between occupations change but the crucial thing is how companies actually react to this and with them it is often the case that they have a qualifying occupation that they have offered for 20 years and they show no willingness to change anything (VET expert, Germany).

However, what is relevant for this study is the finding that IVET-related complementarities are, so far, still carefully preserved by reforms, despite some critical comment. The steel companies and the unions' perspective are brought to convergence through the consultation mechanisms that are typical of this institutional environment, and the steel sector occupational profiles have been re-regulated and integrated accordingly (see Evans and Stroud, 2014).

This form of adaptive response, we believe, provides stronger grounds for incremental innovation and progressive upskilling of the workforce, in line with the I4.0 'promise' of an upskilling scenario. From this point of view, *adaptive responses* are more likely to meet the needs of both companies and workers, establishing a positive feedback loop between social partners and IVET, ensuring a constantly improved flow of skills to the industry, as well as continuous workforce development.

In contrast, the UK is characterised by market-driven IVET provisions typical of LMEs, which assumes that VET providers are able to respond to the needs of the labour market in a direct manner (Markowitsch and Hefler, 2018), lack of meaningful trade union involvement, fragmented governance and a tendency to embrace a radical approach to reforms. The general response within the UK to the pressures created by Industry 4.0 follows this recognisable pattern. Instead of pro-actively devising a long-term national IVET strategy, governments have mostly reacted to the exogenous pressures on the IVET system when these have become too urgent to be ignored. Furthermore, the lack of structures that might help to balance and mediate competing interests of governments, employers and trade unions leads to a tendency to

unilaterally borrow ‘best practices’ from other contexts. This all indicates low mediation with regard to IVET reforms, as well as a scarce reliance on progressive optimisation. We therefore describe the United Kingdom’s response as *impulsive* and consistent with a higher degree of hybridisation when compared to Germany, exemplified by the recent attempt to engage more systematically employers in training provision and to shift from general to industry-specific skills.

In the case of the UK, hybridisation brings in legitimate doubts about the effectiveness of the reforms. For example, there are doubts about the capacity of T-Levels to engage employers on a large scale (Williams et al., 2020). This is consequential to the absence of an institutional tripartite arrangement in LMEs. Where inter-firms’ relations are characterised more by competition, rather than cooperation, and where there is no central representing authority at a sectoral level, occupational standards defined by a panel of employers might not be automatically recognised by other employers. Furthermore, as LMEs are associated with a higher heterogeneity of interests, employers’ panels are likely to represent the interests of large companies, over those of SMEs. One of our interviewees underlines this concern in relation to apprenticeship standards:

You don't really know what effect it's going to have. And as I say there are downsides because bigger companies can influence those apprenticeships much more. So even though most companies are not large companies. They're small and medium enterprises, but they don't have the voice to push around the big players at the table (VET expert, UK)

In this sense, the reforms seem to be incompatible with a fragmented, market-driven IVET system, in which trade unions are largely marginalised and where ‘there is little legal compulsion for employers to engage in skill enhancement’ (Evans and Stroud, 2014: 268).

Further, the new apprenticeship standards in England try to establish some level of coordination between government, employers and IVET providers. In this respect, they represent an attempt to hybridise the market-driven IVET system but lack the trade union component. Cedefop (2018) comments that a potential criticality of ‘allowing employers to have a central role in [VET] design is that it could lead to a proliferation of fairly narrow occupational standards’ (Cedefop, 2018: 79) limiting the breadth of learning that would afford both protection and resilience to workers, resulting in occupational traps.

Overall, while the reforms in the UK (particularly in England), outlined in the previous section, seem to address skills critical to the steel industry, the actual implementation is exposed to the risk of low engagement and non-recognition of standards, on the side of employers, and of occupational bottlenecks, on the side of workers. From this point of view, if IVET is to support the transition of the workforce towards a general 4.0 upskilling scenario, impulsive responses might lack the capacity to establish positive feedback loops between VET and social partners. As the UK case shows, impulsive responses might undermine the capacity of (the steel) industry on the macro-level to stay on track with the requirements imposed by Industry 4.0, with a detrimental effect on the industry/workforce.

Finally, as regards Italy, the overall organisation of vocational education and training has not undergone major structural reforms, except for the introduction of the ITS programme in 2008 and the dual system experimentation started in 2015. Nevertheless, in the last decade Italy’s IVET system appears to have moved away from the ideal-typical Mediterranean capitalism model, borrowing some features of CMEs, especially in terms of apprenticeships and post-secondary co-delivered VET.

Italy’s IVET response to technological change has been proactive, as the country has put in place timely reforms (such as the 2008 ITS programme) to support the transition towards a

more technologically competitive manufacturing industry. The level of mediation is higher than the UK, as social dialogue is more developed, although not as institutionalised as in CMEs. In terms of optimisation, Italy has showed a slightly higher tendency towards hybridisation (e.g. incorporating co-delivery and dual arrangements) compared to Germany. At the same time, reviewing and updating national vocational standards and profiles have assured that curricula remain fit for purpose and programmes maintain their consistency and recognisability within the system.

Overall, it appears that the Mediterranean capitalism model favours more the generation of *adaptive responses*. This can be explained with the ‘rigidity’ (Amable, 2003) of its institutional features, compared to that of LMEs, which prevents quick structural changes (Vallejo-Peña and Giachi, 2018) and hinders resorting to extensive hybridisation. In Italy, hybridisation intended to obviate the lack of specialised technical skills and tackle youth unemployment. Where this takes place, however, potential criticalities emerge. The figure for ITS programmes in the years 2015-2017 shows an employment rate of ITS graduates of about 80% within one year from graduation, highlighting the effectiveness of the programme (INAPP, 2019). This is confirmed by one of our interviewees who comments on the difference between post-secondary ITS programmes and traditional vocational and technical schools:

You can see that something is missing there [in technical schools graduates]. We prefer to take someone from ITS [...] In my opinion there is a basic thing, if I enrol in an ITS programme, it means that I still want to learn something, I have an urge to learn [...] and you can perceive this when they get into the company (Automation manager, Italy).

What is striking, however, is the asymmetry in the activation of ITS courses. The presence of these courses mostly in the north reflects a significant difference in the socio-industrial fabric of the country. Typical of Mediterranean models, Italy has long relied on the central and regional governments in regulating and running general education and school-based VET

programmes. The introduction of higher technical programmes collectively organised and run by training centres, schools, companies and local authorities, brings into the Italian institutional architecture new arrangements, which bring out historical issues related to the uneven social and economic fabric of the country (Trigilia and Burrioni, 2009).

The same geographical asymmetry has been observed for dual apprenticeships (INAPP, 2018). New training arrangements, like those introduced with ITS programmes and dual apprenticeships, appear to work better in those regions with a dense industrial population (especially where this is organised into technological districts) and consequent long-standing IVET tradition. In the other regions, school-based upper-secondary VET remains the most popular choice. Overall, reforms in Italy appear to serve well the transition to I4.0 in those regions (mainly in the north) in which the local institutional environment better supports the hybridisation brought in by the new arrangements, establishing a higher wage/skills equilibrium, and opening up to innovation. This, however, could end up in a geographical divide (north-south) in accessing high-skilled workers with relevant on-the-job training.

More broadly, across all cases, an evident and underscoring theme in the understanding of adaptive and impulsive responses is the institutionalisation of unions' participation in different domains of the political economy, particularly their incorporation in formal feedback mechanisms, meaning by this 'purposefully implemented formal institutional procedures, determining the particular roles of various stakeholders in planned renewal of VET provision' (Markowitsch and Hefler, 2018: 287).

Evidently, in Germany, unions are part of coordinated feedback mechanisms (Ibid.). This goes along with relatively high collective bargaining and employment protection. The vocational reforms described for the German case are well complemented by such institutions, and workers benefit from strong institutional incentives to commit to a lifelong career and acquire

specialised skills (Bosch and Charest, 2008). The broadened training granted by the described adaptive IVET response supports such commitment, thus preserving a pool of skilled workers on which German steel companies can draw on to strengthen their 4.0 agenda and secure competitive advantage.

In Italy too, whilst unions' participation at the IVET level is not institutionalised in formal feedback mechanisms, relatively high employment protection and collective bargaining at the sectoral level work as institutional incentives for workers to invest in firm- and industry-specific skills. At the same time, state/regions coordinated training regulation guarantees that qualifications are based on occupational standards that are broad and inclusive enough to avoid the parcelling out of skills and competencies. This complements the recent reforms that aim to shift the Italian economy towards a high skills equilibrium, despite the underlined differences between north and south.

However, commenting on technology insertion in the steel industry in Germany, and some of the skills and training implications of Industry 4.0, Stroud and Weinel (2020: 309-310) note some potential vulnerabilities to worker representation on training arrangements. Here, drawing on evidence of a fluctuation in the sector union's (IG Metall) power resource and the space created for employers to deviate from sectoral collective agreements (Dribbusch et al. 2018), Stroud and Weinel (2020) suggest a risk to the training arrangements that preserve the holistic nature of occupational profiles. Similar observations are made by the latter with regard to Italy, particularly in relation to arrangements for lesser skilled workers, whom are argued (as a category of worker) to be the most vulnerable to technological unemployment (see, for example, Hirsch-Kreinsen et al. 2019).

Finally, in the United Kingdom (specifically England), the latest reforms attempt ultimately to increase the pool of specialised skills through establishing a vocational route alternative to

general education (T-Levels), relaunching apprenticeships through the introduction of new employer-led standards and engaging more systematically the employers in training provision. However, these impulsive responses appear to be neither complemented nor supported by a deregulated labour market, the absence of trade unions' participation in formal feedback mechanisms, and the absence of measures to safeguard workers from wages fluctuation. Furthermore, the continuous renewal of the VET system itself undermines trust of both workers and employers. Here, institutional incentives for workers to invest in the type of specialised skills offered by the reforms might not be compelling enough, hindering British steel companies in their transition to 4.0 (Evans and Stroud, 2014).

Overall, we find that where institutions are unbalanced in favour of business needs, as in LMEs, expectations carried out by vocational education and training reforms might clash with actual incentives for workers, so feeding back to companies' opportunity to invest in technology and process upgrading in line with Industry 4.0. This finding confirms, although from a slightly different perspective, the risk that Streeck (1992) has pointed out in relation to companies following narrow business interests ending up in reducing incentives and opportunities to grow a pool of specialised talents. Quite the opposite, where we see a more homogeneous distribution of power and interests reflected in national institutions, as in CMEs and Mediterranean capitalism, it appears that the reforms described are more likely to be successful. In this perspective, such institutional contexts seem to offer steel companies a competitive edge (in a globalised and highly competitive industry) to put in practice the Industry 4.0 agenda.

Concluding Remarks

The picture that emerges from our steel sector data is a general shift towards an upskilling scenario resulting from Industry 4.0, rather than the forecasts of deskilling and job loss (see, for example, Hirsch-Kreinsen et al. 2019). Of course, it is indisputable that technological disempowerment/unemployment is a risk, but technology is not a threat *per se* (Braverman, 1974). Indeed, for commentators such as Spencer (2018), the problem at stake is the quality and fair distribution of jobs created by technology, rather than the disappearance of some jobs. From this point of view, ‘the rhetoric of the ‘rise of the robots’ in this respect can become a distraction from other pressing problems created by technology as it evolves within capitalist society’ (Spencer, 2018: 8).

If the issue at stake with Industry 4.0 is not the disappearance of work, but rather its transformation in ways that are both sustainable and rewarding, the way institutions underpinning the labour market respond to the new challenges is crucial (Lloyd and Payne, 2019). In particular, skill formation systems are, we maintain, responsible for bridging the present and the future of industry. Whether the future steel workforce, for example, will be able to meet the requirements of new technological paradigms and adapt to more digital and flexible work will depend on the capacity of IVET systems to build solid occupational foundations, also in terms of soft skills and propensity to lifelong learning. In this respect, the effectiveness of IVET reforms is key, and this, we argue, is correlated with their adaptive or impulsive character. As such, the matter of which social blocs are underpinning of institutional architecture and the power balances that support reforms is crucial. Indeed, as noted by Lloyd and Paine (2019), institutional arrangements that are not based on social partnership are highly volatile, nullifying any effort to reform the system.

In the context of Industry 4.0, a successful transition requires an IVET system capable of intervening on the whole spectrum of occupational profiles, updating and upskilling them to

meet new challenges. However, *impulsive* VET responses might not result in positive outcomes, particularly if they address more short-term business needs rather than cushioning social risks for workers (Lloyd and Payne, 2019). On the other hand, *adaptation* seems to provide stronger grounds for addressing the industry transition as a broader societal challenge. If Industry 4.0 is not only a mere industrial policy issue but has also broad societal and environmental implications, as we believe (see Kagermann, 2017), actively managing the transition is key. Responses characterised by a higher level of proactivity, mediation and optimisation could prove a better steering capacity, than purely impulsive ones. Ultimately, we argue that what lays behind adaptive responses is the balance and distribution of power between different social blocs, which provide a more even and solid basis for a long-term project of societal (and technological) transformation.

References

- Abusland T (2019) *Vocational education and training in Europe: United Kingdom*. Cedefop ReferNet VET in Europe reports 2018.
- Amable B (2000) Institutional complementarity and diversity of social systems of innovation and production. *Review of International Political Economy* 7(4): 645-687.
- Amable B (2003) *The diversity of modern capitalism*. Oxford: Oxford University Press.
- Amable B (2016) Institutional complementarities in the dynamic comparative analysis of capitalism. *Journal of Institutional Economics* 12(1): 79-103.

Amable B and Petit P (2001) The Diversity of Social Systems of Innovation and Production during the 1990s. Cepremap Working Paper No. 2001-15. Available at: <https://ideas.repec.org/p/cpm/cepmap/0115.html>

Angotti R (2019) *Vocational education and training in Europe: Italy*. Cedefop ReferNet VET in Europe reports 2018.

Autor D (2015) “Why Are There Still So Many Jobs? The History and Future of Workplace Automation” *The Journal of Economic Perspectives*, 29(3): 3-30

Bosch G and Charest J (2008) Vocational training and the labour market in liberal and coordinated economies. *Industrial Relations Journal* 39(5): 428-447.

Boyer R (2005) Coherence, diversity, and the evolution of capitalisms—the institutional complementarity hypothesis. *Evolutionary and Institutional Economics Review*, 2(1): 43-80.

Braverman H (1974) *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century*. New York: Monthly Review.

Briken K, Chillas S, Krzywdzinski M and Marks A (Eds.) (2017) Labour process theory and the new digital workplace. In K. Briken, S. Chillas, M. Krzywdzinski, and A. Marks (Eds.) (2017) *The New Digital Workplace: How New Technologies Revolutionise Work*. London: Palgrave. 1-17

Bundesministerium für Bildung und Forschung (2020) Digitalisierung und Nachhaltigkeit – was müssen alle Auszubildenden lernen? Available at: <https://www.bmbf.de/de/digitalisierung-und-nachhaltigkeit---was-muessen-alle-auszubildenden-lernen-12244.html>

Campbell J and Pedersen O (2007) Institutional competitiveness in the global economy: Denmark, the United States, and the varieties of capitalism. *Regulation & Governance* 1(3): 230-246.

Cedefop (2014) *Terminology of European education and training policy: a selection of 130 terms*. 2nd ed. Luxembourg: Publications Office.

Cedefop (2018) The changing nature and role of vocational education and training in Europe. Volume 3: the responsiveness of European VET systems to external change (1995-2015). Cedefop research paper No. 67. Available at: <https://www.cedefop.europa.eu/en/publications-and-resources/publications/5567>

Cedefop (2019) Skills Panorama - Metal & machinery workers: skills opportunities and challenges. Available at: https://skillspanorama.cedefop.europa.eu/en/analytical_highlights/metal-machinery-workers-skills-opportunities-and-challenges-2019-update.

Cedefop (2020). Vocational education and training in Europe, 1995-2035: scenarios for European vocational education and training in the 21st century. Luxembourg: Publications Office of the European Union. Cedefop reference series; No 114.

Crouch C, Streeck W, Boyer R, Amable B, Hall PA and Jackson G (2005) Dialogue on institutional complementarity and political economy. *Socio-economic Review* 3(2): 359-382.

Dribbusch, H., Steffen L. and Schulten, T. (2018) Two worlds of unionism? German manufacturing and service unions since the Great Recession, in S. Lehndorff, H. Dribbusch

- and T. Schulten *Rough waters: European Trade Unions in a Time of Crises*, ETUI, Brussels, pp. 209-233
- Estevez-Abe M, Iversen T and Soskice D (2001) Social protection and the formation of skills: A reinterpretation of the welfare state. In: *Varieties of capitalism: The institutional foundations of comparative advantage*. Oxford: Oxford University Press, pp. 145-183.
- Eurofer (2019) European steel in figures 2019. Available at <https://www.eurofer.eu/assets/Uploads/European-Steel-in-Figures-2019-Final-v2.pdf>
- Evans C and Stroud D (2014) Greening steel work: Varieties of Capitalism and the ‘greening’ of skills. *Journal of Education and Work* 29(3): 263-283.
- Frey C and Osborne M (2017) The Future of Employment: How Susceptible are Jobs to Computerisation. *Technological Forecasting and Social Change* 114: 254-280.
- Hall PA and Gingerich DW (2009) Varieties of capitalism and institutional complementarities in the political economy: an empirical analysis. *British Journal of Political Science* 39(3): 449-482.
- Hall PA and Soskice D (eds) (2001) *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage*. Oxford: Oxford University Press.
- Hassel A (2012) The Paradox of Liberalization - Understanding Dualism and the Recovery of the German Political Economy. *British Journal of Industrial Relations* 52(1): 57-81.
- Kagermann H (2017) Chancen von Industrie 4.0 nutzen. In: Vogel-Heuser B, Bauernhansl T and ten Hompel M. (eds) *Handbuch Industrie 4.0 Bd. 4*. Berlin: Springer Vieweg, pp. 237-248.

Hippach-Schneider U and Huismann A (2019) *Vocational education and training in Europe: Germany*. Cedefop ReferNet VET in Europe reports 2018.

Hirsch-Kreinsen H, ten Hompel M, and Kretschmer V (2019). Digitalisierung industrieller Arbeit. In: ten Hompel M, Vogel-Heuser B and Bauernhansl T (eds) *Handbuch Industrie 4.0*. Berlin: Springer Vieweg, pp. 1-18. https://doi.org/10.1007/978-3-662-45537-1_21-2

INAPP (2018) L'apprendistato tra continuità e innovazione. XVIII rapporto di monitoraggio. Monitoring report. Available at: http://oa.inapp.org/xmlui/bitstream/handle/123456789/435/Inapp_ExecutiveSummary_XV_III_Rapporto_Apprendistato_2018.pdf

INAPP (2019) Relazione ex lege 845/78 art. 20 sullo stato e sulle previsioni delle attività di formazione professionale. Monitoring report. Available at: https://oa.inapp.org/xmlui/bitstream/handle/123456789/480/INAPP_Rapporto%20formazione_2018.pdf

Lloyd C and Payne J (2002) Developing a political economy of skill. *Journal of Education and Work* 15(4): 365–390.

Lloyd C and Payne J (2019) Rethinking country effects: robotics, AI and work futures in Norway and the UK. *New Technology, Work and Employment* 34(3): 208-225.

Markowitsch J and Hefler G (2018) Staying in the loop: Formal feedback mechanisms connecting vocational training to the world of work in Europe. *International journal for research in vocational education and training* 5(4): 285-306.

- Martinelli A, Mina A and Moggi M (2021) The enabling technologies of industry 4.0: Examining the seeds of the fourth industrial revolution. *Industrial and Corporate Change* 30(1): 161-188.
- Murri M, Streppa E, Colla V, Fornai B and Branca TA (2020) Digital transformation in European steel industry: state of art and future scenario. Project report. Available at: <https://www.estep.eu/assets/Uploads/ESSA-Deliverable-2.1-20191118.pdf>
- Naujok, N. and H. Stamm, (2017) *Industry 4.0 in Steel: Status, Strategy, Roadmap and Capabilities*. Keynote Presentation Future Steel Forum, Warsaw
- Nölke A (2019) In search of institutional complementarities: Comparative Capitalism and economic policy reform. *Journal of Economic Policy Reform*. Epub ahead of print 13 September 2019. <https://doi.org/10.1080/17487870.2019.1637582>
- Pring R, Hayward G, Hodgson A, Johnson J, Keep E, Oancea A, Rees G, Spours K and Wilde S (2009) *Education for All: The future of education and training for 14-19 year olds*. London: Routledge.
- Schroeder W (2016) Germany's Industry 4.0 strategy. Rhine capitalism in the age of digitalisation. Friedrich Ebert Stiftung. Available at: https://www.fes-london.org/fileadmin/user_upload/publications/files/FES-London_Schroeder_Germanys-Industrie-40-Strategy.pdf
- Spencer DA (2018) Fear and hope in an age of mass automation: debating the future of work. *New Technology, Work and Employment* 33(1): 1-12.

- Spöttl G and Windelband L (2020) The 4th industrial revolution—its impact on vocational skills. *Journal of Education and Work*. Epub ahead of print 21 December 2020. <https://doi.org/10.1080/13639080.2020.1858230>
- Streeck W (1992) *Social Institutions and Economic Performance: Studies of Industrial Relations in Advanced Capitalist Economies*. London: Sage.
- Stroud D and Weinel M (2020) A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology ‘effects’ in the European steel industry. *New Technology, Work and Employment* 35(3): 297-313.
- Thelen K (2004) *How institutions evolve: The political economy of skills in Germany, Britain, the United States, and Japan*. Cambridge: Cambridge University Press.
- Trigilia C and Burrioni L (2009) Italy: rise, decline and restructuring of a regionalized capitalism. *Economy and Society* 38(4): 630-653.
- Turbin J (2001) Policy borrowing: lessons from European attempts to transfer training practices. *International Journal of Training and Development* 5(2): 96-111.
- Vallejo-Peña A and Giachi S (2018) The Mediterranean variety of capitalism, flexibility of work schedules, and labour productivity in Southern Europe. *Region* 5(3): 21-36.
- White Research, Intrasoftware International, Rina Consulting, Valeu Consulting, with Gibellieri E, Schröder A and Stroud D (2020) *Blueprint for sectoral cooperation on skills: towards an EU strategy addressing the skills needs of the steel sector*. Publications Office of the European Union.

Williams J, Newton B, Takala H, Gloster R and Alexander K (2020) Process Evaluation of Support for T Level Industry Placements: Research Report. Institute for Employment Studies. Available at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/916867/Process_evaluation_of_support_for_T_Level_Industry_Placements.pdf

Zinke G (2019) Berufsbildung 4.0 - Fachkräftequalifikationen und Kompetenzen für die digitalisierte Arbeit von morgen: Branchen- und Berufescreening. BiBB Wissenschaftliche Diskussionspapiere Heft-Nr. 213. Available at:

<https://www.bibb.de/veroeffentlichungen/de/publication/download/10371>