RESEARCH REPORT

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Future of manufacturing

Adaptation of national apprenticeship systems to advanced manufacturing

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European Foundation for the Improvement of Living and Working Conditions

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List of abbreviations

CAD	computer-aided design
CAE	computer-aided engineering
CAM	computer-aided manufacturing
CIM	computer-integrated manufacturing system
CNC	computerised numerical control
CQP	Certificate of Professional Qualification (*Certificat de qualification professionnelle*)
ECVET	European Credit System for Vocational Education and Training
EQF	European Qualifications Framework
FMS	flexible manufacturing systems
GDP	gross domestic product
ICT	information and communication technology
IeFP	education and professional training (*Istruzione e Formazione Professionale*)
IFTS	higher technical education and training (*Istruzione e Formazione Tecnica Superiore*)
ISCED	International Standard Classification of Education
ITS	higher technical education (*Istruzione Tecnica Superiore*)
IVET	initial vocational education and training
KETs	key enabling technologies
MEP	Manufacturing Extension Program [USA]
NACE	Statistical Classification of Economic Activities in the European Community (*Nomenclature statistique des activités économiques dans la Communauté européenne*)
R&D	research and development
SMEs	small and medium enterprises
VET	vocational education and training

See Annex 2 for a list of organisation names and acronyms.

Executive summary

Introduction

Advanced manufacturing covers various aspects related to the application of new and cutting-edge technologies to improve efficiencies and production processes. This technological change inevitably requires an adaptation of vocational training programmes and practices in initial, further and higher vocational education and training (VET).

Apprenticeships combining alternating periods at the workplace and in training institutions are well suited to providing young people with an entry point into the labour market and supplying enterprises with skilled workers. This report examines apprenticeship systems and practices in the manufacturing sector in five EU Member States (Denmark, France, Germany, Ireland and Italy) and two countries outside Europe (Australia and the USA), exploring ways in which apprenticeship training is being adjusted in the context of recent developments in advanced manufacturing. The report identifies a number of general as well as country-specific strengths and weaknesses, successes and barriers to change that require consideration in policymaking at national and European level.

This study uses the working definition of apprenticeship developed by the European Centre for the Development of Vocational Training (Cedefop, 2015). This encompasses a number of important elements such as the long-term character of the training, with systematically alternating periods of training at the workplace and in educational institutions, the contract between the apprentice and the company (including remuneration of the apprentice) and training leading to a qualification.

Policy context

Apprenticeship training and industrial policy in the age of advanced technologies have been addressed by various EU initiatives. In October 2017, the European Commission adopted a proposal for a Council Recommendation for a European Framework for Quality and Effective Apprenticeships, which was adopted by the Council in March 2018. This initiative is linked to the New Skills Agenda for Europe launched in 2016, and also relates to the right to high-quality and inclusive education, training and lifelong learning, as defined in the European Pillar of Social Rights. The Framework builds on previous activities, namely the European Alliance for Apprenticeships (EAfA) launched in 2013. The Commission is also to launch demand-driven apprenticeship support services to facilitate the introduction, reform and improvement of apprenticeship systems. The official launch is scheduled for 8 November 2018 in Vienna as part of the 3rd European Vocational Skills Week, celebrating the five years of EAfA.

The close linkage between industrial competitiveness, advanced technologies and digitisation of the economy and high-quality initial vocational education and training (IVET) was highlighted in the Commission's Communication on the Digital Education Action Plan adopted in January 2018, which emphasised the need to foster investments in skills and talent development in order to support a successful transition from traditional to advanced manufacturing.

Key findings

- All seven countries have public industrial policy initiatives aimed at fostering advanced manufacturing, but the link between these initiatives and IVET and apprenticeship policies and practices is relatively weak. Only in Denmark and Germany has a comprehensive approach to modernising and adjusting apprenticeship training been developed in response to new skills requirements.
- There are significant differences in the approach to apprenticeship training in the investigated countries. Denmark and Germany are the only countries where apprenticeship is the only or most widespread form of initial VET; it is characterised by a strong involvement of social partners in governance and the modernisation of occupations and training practice. This is also the case, to a lesser extent, in Ireland, which has traditionally offered a relatively limited number of apprenticeship programmes and provided for more modest opportunities for social partner involvement.
- In countries such as Australia and the USA, only limited numbers of occupational programmes and respective apprenticeship programmes are available, including those of relevance for the manufacturing sector, and there has been weak social partner involvement, often centring primarily on input from employers.
- In countries such as Italy and the USA, the apprenticeship system and the capacity to adjust and modernise suffer from the absence of national governance structures (formally recognised national apprenticeship qualifications) at least in the former's case for the vast majority of apprenticeships.
- With the exception of Denmark and Germany, and to a lesser extent Ireland, apprenticeship training competes with other IVET pathways in all the other countries studied. Young people who are interested in a career in manufacturing are often attracted to academic pathways, which are more prestigious and may lead to a higher lifetime income.
- In most of the countries studied, apprenticeship training is attractive for employers in the manufacturing sector, in particular because of the close linkage of theoretical and practical education and training, and the opportunity for employers to be involved in the development of programmes and to adjust training needs to meet company-specific requirements.

- Across all the countries, the boundaries between apprenticeships and the higher education system inhibit the further development of 'higher apprenticeships'. In countries where such career paths exist, the latter often have little or no link with the apprenticeship system and have limited appeal for companies.

Policy pointers

- Apprenticeship training should be regarded as an integral part of modern industrial policy. To be successful, industrial policies fostering the transition to advanced manufacturing and implementing Industry 4.0 require a complementary strategy of Apprenticeship 4.0. The linkage between industrial policy and IVET policy (including apprenticeships) is still missing in most of the countries studied. National governments should seek the active involvement of sectoral social partners and IVET institutions in the design and implementation of industrial policies. Priority should be given to the adaptation of training and education curricula to meet changing skills requirements in manufacturing.
- The European Commission should foster initiatives to involve sectoral social partners and IVET institutions more actively in industrial policy dialogue. At EU level, the renewed EU Industrial Policy Strategy and related initiatives could give greater emphasis to IVET and assign a more central role to apprenticeships to support the modernisation of European manufacturing.
- Modernisation processes are often hampered by structural weaknesses in apprenticeship systems and practices. Many barriers and factors hindering adjustments in relation to advanced manufacturing are related to general structural weaknesses, such as the limited attractiveness of apprenticeships for learners and companies, an unclear division or fragmentation of responsibilities among the involved players and, in some cases, a lack of coordination among institutions at local, regional and national level. Such weaknesses need to be addressed urgently in order to strengthen apprenticeship provision within the initial and higher VET system and 'make it fit' to cope with technological change.
- Apprenticeships can have positive labour market and economic impacts if certain quality criteria for learning and working conditions, as well as for framework conditions, are in place. It will be important to implement such conditions that are described in the 14 criteria set out in the European Framework for Quality and Effective Apprenticeship across Member States. It would be important to focus, however, not only on the broad level of national IVET policy, but also on specific sectors such as the manufacturing sector by actively involving social partners, IVET institutions and relevant public authorities.
- The concept of higher apprenticeship needs to be explored further and a common definition at levels equivalent to levels 6, 7 and 8 of the European Qualification Framework should be considered. There is a need to differentiate between various forms of higher apprenticeship, and to foster and exchange innovative approaches to it in the manufacturing sector.

Introduction

Scope of the research

This comparative report is part of a study, 'Policy developments and practices of apprenticeship training in selected EU Member States and world competing regions', carried out in five EU (Denmark, France, Germany, Ireland and Italy) and two non-EU (Australia and the USA) countries. The analysis presented in this study was conducted within the framework of the pilot project The Future of Manufacturing in Europe, proposed by the European Parliament and delegated to Eurofound by the European Commission (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs).

This research was carried out in response to the increasing interest shown by policymakers in reducing the generally high levels of youth unemployment and the consequent requirement to integrate young people into the labour market. To be effective, however, it is essential to ensure that any initiatives undertaken in relation to apprenticeship training correspond with the needs of the labour market and the ways in which new technologies are transforming work organisation and production processes across all sectors, particularly manufacturing.

This report seeks to:

- provide an analytical comparative overview of apprenticeship systems in the selected countries;
- review policy developments in response to labour market shifts, changes in employment, career and mobility patterns, and technological and structural change.

In the countries studied, such developments take different forms such as:

- amendments and/or development of legislation;
- changes to funding regimes;
- revision of the training content in existing apprenticeship programmes and the development of new ones.

This comparative report takes into consideration seven country studies. Countries were selected on the basis of two main criteria.

- Manufacturing and advanced manufacturing are important for the national economy and/or are highly relevant for national industrial policy.
- Apprenticeship is either a significant part of national systems of vocational education and training (VET) or a priority of policy initiatives to modernise and/or adapt national VET systems.

The country studies were carried out by national experts on the basis of desk-based research, underpinned by between four and eight in-depth interviews per country with key players and stakeholders representing public authorities, employer organisations, trade union organisations, training providers and research institutes.

The findings from this research will feed into the policy debate around the role of apprenticeship training in the future development of manufacturing. They will inform policymaking in the context of current or planned reforms of apprenticeship systems and reforms of curricula for apprenticeship qualifications, all of which will be dependent on the relationship between education and training policies and industrial policies.

Report structure

Chapter 1 outlines the wider economic and labour market contexts within which the national apprenticeship systems operate. Particular emphasis is placed on the impact of new technologies and the need for a high-skilled and adaptable workforce in manufacturing and advanced manufacturing.

Chapter 2 presents the key features of national apprenticeship systems (regulatory framework, governance structure and financing mechanisms) and provides statistical data on apprentices and apprenticeships. It also highlights some of the key challenges to be addressed to ensure the successful implementation and development of current apprenticeship systems.

The focus of Chapter 3 is on the role of apprenticeship training in relation to manufacturing and advanced manufacturing. It examines the main requirements arising, in particular, from technological change in manufacturing and explores ways in which apprenticeship systems are responding to these changes.

Chapter 4 points to the key strengths and weaknesses of apprenticeship systems and programmes in the different countries. It also examines the different success factors and barriers to the development of apprenticeship systems in the context of changing skill needs within manufacturing and advanced manufacturing.

Chapter 5 summarises the main conclusions emerging from the research and highlights the policy implications for European VET policy.

Key terms at a glance

Apprenticeships and higher apprenticeships

There is no single agreed definition of apprenticeships, since they have developed over time according to local traditions and labour market needs. Nevertheless, apprenticeship systems tend to have similar key characteristics.

At the global level, the International Labour Organization (ILO) considers that:

> *Quality apprenticeships are a unique form of vocational education and training, combining on-the-job training with off-the-job learning, which enable learners from all walks of life to acquire the knowledge, skills*

> *and competences required to carry out a specific occupation. They are regulated and financed by laws and collective agreements and policy decisions arising from social dialogue, and require a written contract that details the roles and responsibilities of the apprentice and the employer; they also provide the apprentice with remuneration and standard social protection coverage. Following a clearly defined and structured period of training and the successful completion of a formal assessment, apprentices obtain a recognized qualification.*
>
> (ILO, 2017, pp. 3–4)

At European level, the European Centre for the Development of Vocational Training (Cedefop), provides a working definition of 'apprenticeship' in its glossary of vocational training policy that is used as a reference in the seven country reports as well as this comparative report.

> *Systematic, long-term training alternating periods at the workplace and in an educational institution or training centre, which leads to a qualification. An apprentice is contractually linked to the employer and receives remuneration (wage). An employer assumes responsibility for the company-based part of the programme.*
>
> (Cedefop, 2015, p. 5)

The European Commission has contributed to a better understanding of the distinction between apprenticeship and work-based learning. It defines work-based learning as 'it is directly linked to the mission of VET to help learners acquire knowledge, skills and competences which are essential in working life' and presents three main models:

- alternance schemes or apprenticeships typically known as the 'dual system';
- work-based learning as school-based VET which includes on-the-job training periods in companies;
- work-based learning integrated in a school-based programme, through on-site labs, workshops, kitchens, restaurants, junior or practice firms, simulations or real business/industry project assignments (European Commission, (2013a, pp. 5–7).

In short, an apprenticeship is a form of work-based learning, but not all work-based learning is an apprenticeship.

There is also no specific definition for 'higher apprenticeships'. In Germany, for example, there is the *Meister* qualification for apprentices who take a further examination made up of four parts – practical, theoretical, economic and legal, and pedagogical – but generally speaking the term 'higher apprenticeship' is not used as such.

In countries such as France and Ireland, the beginnings can be seen of a trend to launch apprenticeships that are placed at a higher level on the national qualifications framework than traditional apprenticeships, with the off-the-job training generally done at an institute of higher education; these are considered as 'higher' apprenticeships.

In Italy, higher apprenticeships have existed since 2003, but only in small numbers.

Advanced manufacturing

'Advanced manufacturing' is a multifaceted term that has been used quite broadly in international research and economic policy debate in an attempt to capture various aspects related to the application of new, cutting-edge technologies, techniques and skills aiming at generating efficiencies and improvements to production processes (Shipp et al, 2012). Examples of such technologies – also known as key enabling technologies (KETs) – include:

- collaborative/advanced robotics;
- three-dimensional (3D) printing;
- new materials;
- nanotechnologies;
- micro- and nanoelectronics;
- industrial biotechnology;
- photonics.

The Organisation for Economic Co-operation and Development (OECD) glossary of statistical terms defines 'advanced manufacturing technology' as

> *computer-controlled or micro-electronics-based equipment used in the design, manufacture or handling of a product. […] Typical applications include computer-aided design (CAD), computer-aided engineering (CAE), flexible machining centres, robots, automated guided vehicles, and automated storage and retrieval systems. These may be linked by communications systems (factory local area networks) into integrated flexible manufacturing systems (FMS) and ultimately into an overall automated factory or computer-integrated manufacturing system (CIM).*
>
> (OECD, 2013)

At EU level, European Commission initiatives to strengthen European industry were adopted in response to the 2008 global economic and financial crisis. More recently, EU initiatives have focused on supporting the digitisation of industry (European Commission, 2016a) and smart, innovative and advanced industries and technologies (European Commission, 2017d).

In the countries analysed in this study, different terms are used in public policies and in the respective industrial and economic policies. US industrial policy clearly refers to advanced manufacturing, whereas in EU countries such as Germany and Italy, the concept of Industry 4.0 is used more frequently. Other terms such as 'industrie du futur' in France basically describe the same aspects. Increased cooperation between French, German and Italian government-led initiatives emerged recently with the publication in June 2017 of a shared action plan setting out a roadmap for trilateral cooperation on digitising the manufacturing industry (Platform Industrie 4.0, 2017).

1 Economic and labour market context

Key trends in the economic role of manufacturing

Manufacturing is a key pillar of the economy in all the countries studied. The sector's share of gross value-added in 2014 varied from around 11% in France, 14% in Denmark and 15% in Italy to 21% in Ireland and 23% in Germany (Eurostat, 2017a). Looking beyond the EU, the share of value-added generated by manufacturing in the US economy reached about 12% in 2015 (Levinson, 2017), while the share in Australia reached about 7% in 2016. Although the share has declined in recent years in Australia, France and Italy, it has remained relatively stable in the USA and has increased in Denmark, Germany and Ireland.

Among all EU countries, the German manufacturing sector occupies the leading rank with an annual turnover of more than €1.9 trillion as well as over seven million employed in 2015. This is also illustrated by the fact that, in 2014, around 30% of the gross value-added of manufacturing in the EU28 was generated in Germany (Eurostat, 2017b).

In the European ranking, Germany is followed by France and Italy, where both have a manufacturing sector with a turnover of more than €0.8 trillion and three million employed. Although the size of the country means that the manufacturing sector is relatively small in terms of turnover and employment in Denmark and Ireland, Danish manufacturing has a global reputation for products ranging from generators, pumps and thermostats, to wind turbines, robotics and pharmaceuticals. Manufacturing is also a critical component of the Irish economy, providing employment (directly or indirectly) for a significant part of the workforce and across a broad range of occupations. It is a major source of exports and an important driver of research and development (R&D) and innovation.

The US value-added in manufacturing was USD 2.1 trillion (€1.8 billion as of 14 May 2018) in 2014, occupying the second rank worldwide behind China (Levinson, 2017). According to the *2016 Global Manufacturing Competitiveness Index* report, the USA is expected to regain its position as the world's leading manufacturing nation by 2020, double that of China (Deloitte Global, 2016).

In Australia, despite the falling share of gross domestic product (GDP) and employment, the real output of manufacturing (adjusted for inflation) peaked in 2008 at AUD 113 billion (€71 billion) but fell to just under AUD 100 billion (€63 billion) in 2015 (Australian Bureau of Statistics, 2016). Total demand for manufacture continues to grow in Australia, but an increasing share of this demand is met by imports. As a result, domestic manufacturing is under intense competitive pressure and this provides an important context for the capacity of the industry to invest in training.

In four of the countries studied, the manufacturing sector was hit harder by the economic and financial crisis than the national economy as a whole. Since the 2008 crisis, average economic growth in France has not exceeded 0.5% per year, with manufacturing the sector that has suffered the most. Industrial value-added has increased by only 0.3% on average (compared with +0.5% in the EU as a whole). The same applies to Italy, where economic growth was low and value-added in manufacturing even declined slightly between 2008 and 2016.

The US GDP suffered serious declines in late 2008 to early 2009. Manufacturing production declined more than did GDP as a whole between 2007 and 2009, but recovered somewhat faster than GDP. As of 2015, manufacturing output stood nearly 16% higher than the pre-crisis 2007 levels, while GDP in 2015 averaged only 10% more than in 2007.

The development of the Australian economy was also considerably more positive than in manufacturing. The value-added of manufacturing fell by about 4% between 2007 and 2015 while the combined value-added of all industries increased by more than 40% (Australian Bureau of Statistics, 2016).

While the trends in manufacturing have largely developed in parallel to the whole economy in Germany, the growth of gross value-added was higher for manufacturing than for all sectors combined in Denmark and Ireland between 2008 and 2016 (Eurostat, 2017a).

Employment in manufacturing

Germany was the only EU Member State, apart from Slovakia, where employment in manufacturing increased between 2008 and 2015. The decline of manufacturing jobs since 2008 has been most considerable in Australia and Italy (Table 1).

Eurostat does not use the term 'advanced manufacturing', but instead refers to 'high-tech manufacturing'[1] in its statistics on turnover covering the manufacture of:

- basic pharmaceutical products and pharmaceutical preparations (NACE 21);
- computer, electronic and optical products (NACE 26);
- air- and spacecraft and related machinery (NACE 30.3).

Data on turnover and employment are available for EU countries.

1 To compile statistics on high-tech economic activities, Eurostat uses an aggregation of the manufacturing industry according to technological intensity and based on NACE Rev.2 for compiling aggregates related to high technology, medium-high technology, medium-low technology and low technology. The list of NACE groups can be found on the Eurostat website (http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries).

Table 1: Number employed in the manufacturing sector, 2008–2015 (millions)

	2008	2009	2010	2011	2012	2013	2014	2015	Change between 2008 and 2015
Denmark	0.39	0.31	0.29	0.37	0.36	0.35	0.36	0.36	-5.2%
France	n.a.	n.a.	3.11	3.06	3.03	3.01	3.01	n.a.	-2.9%*
Germany	7.1	6.7	6.92	7.14	7.17	7.22	7.27	7.26	+2.2%
Ireland	0.2	0.17	0.17	0.17	0.16	0.16	0.19	n.a.	-3.0%**
Italy	4.41	4.17	4.00	3.93	3.85	3.73	3.65	3.67	-16.8%
Australia	1.0	0.97	0.95	0.94	0.94	0.9	0.88	0.86	-14.8%
USA	15.9	14.2	14.08	14.33	14.69	14.87	15.1	15.34	-3.6%

** 2010 to 2014, ** 2008 to 2014*
Note: *n.a. = not available.*
Source: *For EU countries: Eurostat annual detailed enterprise statistics for industry, NACE section C, 2017; for the USA: OECD STAN industrial analysis; for Australia: Australian Bureau of Statistics (2016)*

France, Germany, Italy and Ireland were among the five countries with the highest turnover in high-tech manufacturing in the EU in 2013. France, Germany and Italy were among the five countries with the highest absolute employment.

Turnover, as well as employment development between 2008 and 2014 and 2015, respectively, indicates different dynamics within the EU; whereas employment increased in Denmark and Germany, it was almost stable in Ireland and went down in France and Italy (Table 2).

The most important decline in employment can be witnessed in France. Industrial employment in France has been declining since the 1980s. The two main factors in this trend are the automation of production and the outsourcing of certain industrial activities to the service sector. The branch of specialised, scientific and technical services[2] that benefited from this wave of outsourcing created 208,000 jobs between 2008 and 2015, making it possible to offset almost half of industrial job losses. This branch of specialised, scientific and technical services accounts for 5.6% of total employment in France;

Table 2: Turnover and employment in the high-tech manufacturing sector, 2008–2014 (EU countries)

	2008	2009	2010	2011	2012	2013	2014	2015	Change between 2008 and 2014
Turnover (€ billion)									
Denmark	10	10	12	13	14	14	16	n.a.	+62.4%
France	76	67	71	70	70	73	68	n.a.	-10.2%
Germany	128	100	109	117	113	118	121	n.a.	+21.3%*
Ireland	49	55	47	50	44	40	n.a	n.a.	-19.9%**
Italy	50	46	49	50	47	47	44	n.a.	-11.7
Number employed (thousands)									
Denmark	43.7	43.2	44.7	46.7	47.2	42.2	46.4	47.3	+8.2%
France	306.9	288.5	269.3	279.0	257.7	254.3	253.3	262.5	-14.5%
Germany	605.6	639.2	617.9	619.3	617.2	667.4	659.3	649.6	+7.3%
Ireland	60.6	58.0	58.0	54.9	55.8	56.7	56.5	60.9	+0.5%
Italy	241.1	247.8	236.1	218.9	218.0	214.8	216.5	213.8	-11.3%

** 2009 to 2004; ** 2008 to 2013*
Note: *n.a. = not available.*
Source: *Eurostat, high-tech statistics employment (2016) and economic data (2017)*

2 This branch includes specialised professional, scientific and technical activities such as scientific research and development, architectural and engineering activities, technical testing and analysis, and legal and accounting activities. These activities require a high degree of training, and make specialised knowledge and skills available to users (Eurostat).

according to Eurostat, it employed 1.46 million workers in 2015 compared with 3.2 million workers in the industrial sector. High-tech jobs in the services sector therefore accounted for almost half of all industrial jobs (46%), a proportion much higher than in the EU on average (35%) or, for instance, in Germany (28%). While not all of these workers pertain to the manufacturing sector, this development of high-tech jobs in the service sector rather than the industrial sector, due to a process of outsourcing of certain functions from the latter to the former, is a specificity of the French model that also affects manufacturing.

The most significant increase in productivity per employee in high-tech manufacturing is seen in Denmark. This reflects a development where increased automation and robotisation have made the Danish manufacturing industry more competitive and, in some respects, reversed the trend of the early 2000s of outsourcing production to lower-cost countries in Europe and Asia. Even though outsourcing continues, many enterprises are now relocating their production lines back to Denmark as higher wage costs are offset by increased productivity, while outsourcing typically concerns low-tech manufacturing (Rasmussen, 2016). Productivity per employee has also increased in France, while it has fallen considerably in Ireland and more slightly in Germany and Italy.

A further Eurostat statistic on the share of employment combines 'high- and medium-high technology manufacturing sectors' comprising the three NACE codes listed on page 3 for high-tech manufacturing as well as the manufacture of:

- chemicals and chemical products (NACE 20);
- weapons and ammunition (NACE 25.4);
- electrical equipment (NACE 27);
- machinery and equipment n.e.c. (NACE 28);
- motor vehicles, trailers and semi-trailers (NACE 29);
- other transport equipment (NACE 30) excluding building of ships and boats (NACE 30.1) and excluding manufacture of air- and spacecraft and related machinery (NACE 30.3);
- medical and dental instruments and supplies (NACE 32.5).

The share of employment in high- and medium-high technology manufacturing sectors in total employment remained relatively stable between 2008 and 2016, with slight increases in Ireland and Italy and decreases in Denmark, France and Germany. Germany and Italy ranked above the EU average, while Denmark, Ireland and France were below it (Table 3).

The trend in employment as analysed by the European Commission's KETs Observatory[3] indicates a positive development of employment for advanced manufacturing technologies and nanotechnology in all the EU countries studied between 2007/2008 and 2012/2013, while the development in advanced materials, industrial biotechnology, micro- and nanoelectronice, and photonics largely differs in the different countries (Table 4).

For the non-EU countries studied, US national statistics refer to the high-tech manufacturing industries[4] defined by the large concentration of engineers working in them. High-tech manufacturing industries accounted for about 2% of total employment (2.8 million jobs) and 8% of total output in 2014. Over the past 20 years, the share of services in total high-tech employment has increased; about one million jobs were lost in high-tech manufacturing, while the number of jobs in high-tech services increased by 3.4 million. In contrast, the share of manufacturing in total high-tech output has only fallen slightly (Wolf and Terrell, 2016).

According to the World Development Indicators from the World Bank, high-tech exports from the USA fell by about 30% between 2007 and 2016. The share of high-tech exports in the total of manufactured exports decreased,

Table 3: Employment in high- and medium-high technology manufacturing sectors, 2008–2015 (% of total employment)

	2008	2009	2010	2011	2012	2013	2014	2015	2016
EU28	5.9*	5.6	5.5	5.6	5.6	5.6	5.7	5.7	5.8
Denmark	5.5*	5.0	5.2	5.4	5.1	5.0	5.0	5.1	5.0
Germany	9.9*	9.9	9.7*	9.8*	9.7	9.6	9.7	9.9	9.8
Ireland	4.6*	4.9*	5.0	5.1	5.0	5.2	4.9	5.2	5.2
France	5.4*	5.1	4.8	4.8	4.6	4.6	4.4*	4.4	4.4
Italy	6.0*	6.0	5.8	5.8	5.9	5.9	6.0	6.1	6.1

** break in time series*

Source: *Eurostat, employment in high- and medium-high technology manufacturing sectors and knowledge-intensive service sectors (tsc00011, last updated 10 May 2017)*

3 For a detailed definition of KETs applied by the Observatory see Van de Velde et al (2015).

4 High-tech manufacturing industries consist of: petroleum and coal products; basic chemicals; resins, synthetic rubber, and artificial synthetic fibres and filaments; pharmaceuticals and medicine; industrial machinery; commercial and service industry machinery manufacturing, including digital cameras; engine, turbine and power transmission equipment; other general purpose machinery; computer and peripheral equipment manufacturing, excluding digital cameras; communications equipment; audio and video equipment; semiconductors and other electronic components; navigational, measuring, electromedical and control instruments; manufacturing and reproduction of magnetic and optical media; electrical equipment manufacturing; and aerospace products and parts.

Table 4: Trends in employment in KETs (2007/2008 to 2012/2013)

	Advanced manufacturing technologies	Advanced materials	Industrial biotechnology	Micro- and nanoelectronics	Nanotechnology	Photonics
EU average	33%	-3%	+43%	-3%	+85%	1%
Denmark	54%	n.a.	n.a.	25%	166%	124%
France	33%	1%	28%	0%	107%	21%
Germany	35%	15%	6%	17%	106%	67%
Ireland	44%	6%	-28%	-51%	4%	21%
Italy	19%	-14%	52%	6%	108%	-14%

Note: *n.a. = not available.*
Source: *European Commission, KETs Deployment Visualization Tool (https://ec.europa.eu/growth/tools-databases/kets-tools/kets-deployment)*

reaching a low of 17.8% in 2012, before increasing to reach 19% in 2015.

In contrast, high-tech exports increased between 2007 and 2015 in Australia by about 30% and the share of high-tech exports in the total of manufactured exports increased from 10.3% to 13.5%. However, Australian manufacturers still generally have low rates of exporting. Successful Australian manufacturers, particularly advanced manufacturers, typically occupy unique niches in international markets.

Impact of innovation

The use of advanced manufacturing technologies is likely to increase as innovation systems in the countries become more performant.

The European Innovation Scoreboard[5] shows that Denmark and Germany have an innovation performance well above the EU average and are therefore classified as 'innovation leaders'. France and Ireland, with a performance above or close to that of the EU average, as well as Australia and the USA, are classed as 'strong innovators'. Italy is the only country studied in this report to be classified as a 'moderate innovator' due to a performance below that of the EU average (European Commission, 2017a). The Innobarometer 2015 survey, however, shows that 44% of the Italian enterprises were already using advanced manufacturing technologies[6] and that the share of enterprises that had invested more than 5% of their total turnover in R&D since 2012 was above the EU average (European Commission, 2015a) (Table 5).

Table 5: Innovation, R&D and use of advanced manufacturing technologies (%)

	Classification according to European Innovation Scoreboard 2017	Investment in R&D*	Enterprises that have used advanced manufacturing technologies	Enterprises that plan to apply advanced manufacturing technologies in the next 12 months	High-tech exports (manufactured exports) 2015
EU average	n.a.	9	44	41	16.9
Denmark	Innovation leader	14	51	46	16.0
Germany	Innovation leader	10	34	34	16.7
Ireland	Strong innovator	13	33	35	26.8
France	Strong innovator	7	36	47	26.8
Italy	Moderate innovator	11	44	31	7.2**
Australia	Strong innovator	n.a.	n.a.	n.a.	13.5
USA	Strong innovator	9	30	29	19.0

** Share of enterprises that had invested more than 5% of their total turnover in R&D since January 2012; ** 2014*
Note: *n.a. = not available.*
Source: *European Commission (2015a, 2017a); World Bank, World Development Indicators*

5 The European Innovation Scoreboard (http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en) measures the performance of innovation systems by the average performance on 27 indicators in key areas such as human resources, attractiveness of research systems and innovation friendliness of environment, innovation efforts at company level, and impact on employment and sales.

6 Innobarometer defines advanced manufacturing technologies as sustainable manufacturing technologies (that is, technologies that use energy and materials more efficiently and drastically reduce emissions), information and communication technology (ICT) enabled intelligent manufacturing (that is, technologies which digitalise the production processes) and high-performance manufacturing, which combines flexibility, precision and zero defects (for example, high-precision machine tools, advanced sensors or 3D printers).

In Australia, one response to intensified competitive pressure has been for manufacturing to significantly increase its investment in R&D. Over the period from 1992/1993 to 2013/2014, R&D intensity (or expenditure on R&D as a share of net output) increased by close to 50%. However, the R&D intensity of manufacturing across the OECD has also increased markedly and exceeds that in Australia by around 70% (Department of Industry, 2014).

Overview of industrial policy initiatives addressing advanced manufacturing

Advanced manufacturing as a reference term in EU policy initiatives

While quite broadly used in US literature, the term 'advanced manufacturing' is increasingly used by the European Commission in the context of initiatives to revitalise the manufacturing sector in Europe. Its communication update, 'A stronger European industry for growth and economic recovery' (European Commission, 2012), focuses on priority areas such as advanced manufacturing technologies, KET, bio-based products, sustainable industrial and construction policy and raw materials, clean vehicles and smart grids. The digitisation of industries is seen as a key to growth and competitiveness (Ambroziak, 2014; Dhéret and Morosi, 2014; European Commission, 2014b, 2016a, 2017d).

Smart, more efficient and sustainable manufacturing processes, technologies, systems and methods are also at the centre of the Vanguard Initiative pilot on Efficient and Sustainable Manufacturing. This was launched in 2013 by the regional governments of 10 EU regions with the support of the European Commission. It currently brings together 30 'model' regions that have made

> *a political commitment […] to use their smart specialisation strategy to boost new growth through bottom-up entrepreneurial innovation and industrial renewal in European priority areas.*[7]

According to the work of the Task Force on Advanced Manufacturing for Clean Production,[8] advanced manufacturing is understood as

> *manufacturing technologies and production processes which have the potential to enable manufacturing industries to improve productivity (production speed, operating precision, and energy and materials consumption) and/or to improve waste and pollution management in a life-cycle perspective.*
>
> (European Commission, 2014c, p. 6)

This orientation is linked to the expectation of a continuing structural change towards a superior quality of research-intensive industrial products and with the vision of environmentally sustainable manufacturing processes and methods. The 'return' on the economic importance of industry does not emphasise the preservation of existing structures, but focuses on the setting up of new industries in new growth markets (European Commission, 2014a).

An important focus of EU industrial policy is the implementation of the EU strategy on KETs. KETs in this context are defined as micro- and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics and advanced manufacturing technologies. The strategy is supported by a high-level group that was established in 2013 and published its recommendations in 2015 (European Commission, 2015c). Further research commissioned by the European Commission to boost the industrial deployment of KETs in Europe identified KETs areas in which Europe should strategically invest, ranging from robots to biometric identification techniques or data mining (Executive Agency for Small and Medium Sized Enterprises, 2017). It also analysed missing capabilities and barriers to the development of additive manufacturing (3D printing) in Europe (European Commission, 2016c).

In addition, the development of skills relevant for KETs (European Commission, 2016b) and access-to-finance conditions met by companies investing in KETs have been judged by EIB InnovFin Advisory Services to be important aspects (European Investment Bank, 2016). Special attention is given to small and medium enterprises (SMEs) and their access to KETs including advanced manufacturing technologies (European Commission, 2016d).

At EU level, the need to improve people's skills in relation to advanced manufacturing is further emphasised in a recent Communication from the European Commission. This states that

> *the industrial transformation provides enormous opportunities, but reaping them will require substantial investment in advanced manufacturing, people's skills and talents, as well as intangible assets like research and innovation.*
>
> (European Commission, 2017d, p. 4)

Although there is no explicit mention of initial vocational education and training (IVET), particularly apprenticeships, the Communication acknowledges that developing a skilled labour force is essential to making the transition from traditional to advanced manufacturing. In November 2017, the European Council called on the European Commission to build on its Communication and put forward a more comprehensive and long-term strategy for 2030 and beyond.

7 http://www.s3vanguardinitiative.eu/ambitions

8 The task force was established in 2012 by the European Commission, led by DG ENTR, with participation of DG Research and Innovation, Joint Research Centre, DG Education, Youth, Sport and Culture, DG Communications Networks, Content and Technology, DG Competition, DG Energy, DG Employment, Social Affairs and Inclusion, DG Regional and Urban Policy, DG Trade and the Secretariat-General. During 2013, the task force consulted with EU Member States, industry and other stakeholders. Two public hearings were held, a series of workshops were organised and an online consultation was open from March to June 2013 (https://ec.europa.eu/digital-single-market/en/news/advancing-manufacturing-advancing-europe-report-task-force-advanced-manufacturing-clean).

Advanced manufacturing as a reference term in national industrial policies

The definitions and terms used in industrial policy initiatives vary as advanced manufacturing is not a readily used concept in most of the seven countries studied. Although concepts refer to the future of manufacturing in all the countries studied, approaches differ, ranging from narrower definitions focusing on R&D intensity (Australia), the use of advanced technologies in production (Denmark) and the use of digital technologies (France), to broader definitions including new ways to manufacture existing products as well as new products (USA), the entire digitalisation and interconnectedness of value chains in the manufacturing industry by information and communication technology (Germany and Italy), and the influence of lean principles, sustainable manufacturing and the pervasive use of ICT (Ireland). The distinction between advanced manufacturing and manufacturing is generally not easy to make in all these countries.

Advanced manufacturing is defined by the US government as

> *a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by physical and biological sciences, for example nanotechnology, chemistry and biology. This involves both new ways to manufacture existing products and the manufacture of new products emerging from new advanced technologies.*
>
> (PCAST, 2011, p. 9)

But because advanced manufacturing encompasses 'new ways' to manufacturing existing products, there is no clear way to distinguish advanced manufacturing from other manufacturing.

In contrast, the concept of advanced manufacturing in Australia is not limited to a specific sector, but it is defined broadly as it encompasses any adoption of technology or process that enhances productivity. The significance of the latter is that advanced manufacturing is defined primarily not by the nature of the final product ('high tech') but by the advanced technologies, including advanced services used in manufacturing or even in the provision of services (Willox, 2014). Australia is the only country among those studied where attempts have been made to apply quantitative indicators for advanced manufacturing. The Australian Federal Department of Industry, Innovation and Science uses a composite definition of advanced manufacturing, as it encompasses high R&D intensity – double that of the manufacturing industry as a whole.

In Denmark, the term 'advanced manufacturing' has no universally accepted official definition, but similarly is understood as enterprises employing new, cutting-edge technologies such as computerised numerical control (CNC), computer-aided design/computer-aided manufacturing (CAD/CAM), advanced robotics, industrial biotechnology, 3D printing, nanotechnologies and photonics. As highlighted in the Danish country report, the line between what is advanced manufacturing and merely manufacturing in general is blurred and indistinct.

In Ireland, the term 'advanced manufacturing' is not used as such, but there is an understanding that:

- 'by 2020 manufacturing will be different from what it is today' (Forfás, 2013, p. 6);
- factories will be smart, virtual and digital.

According to the Forfás policy report, these concepts relate to a far too distant (and unrealistic) future for many manufacturers in Ireland

> *the fact is that Lean Principles, Sustainable Manufacturing and the pervasive use of ICTs cannot be ignored by any manufacturing firm in operation today – regardless of scale or ownership.*
>
> (Forfás, 2013, p. 7)

A strong reference to the manufacturing of the future and future industries also characterises the French debate on advanced manufacturing. Here, the focus is on digital technologies, considered central to current industry developments such as predictive analysis, the internet of things, advanced materials, numerical simulations and high-frequency calculations.

In Germany and Italy, public policies addressing advanced manufacturing are very much based on the concept of Industry 4.0. In both countries, this term has emerged as the main reference used by all political parties and social partners, as well as by governments at federal and regional level, as a key to current and future industrial competitiveness and the main driver for innovation.

Industry 4.0 has been defined as the entire digitalisation and interconnectedness of value chains in the manufacturing industry by ICT. Software-intensive embedded systems (cyber-physical systems) and an 'internet of things and services' furthermore enable new monitoring and control methods as well as real-time decision processes in complex production systems across the entire value chain (Spath, 2013). Thus, the concept of Industry 4.0 goes beyond mainly technology-driven changes. It also addresses organisational and business-related aspects of new production systems. From this holistic perspective, the key challenge emerging in the context of 'advanced' or 'smart' manufacturing has to be seen in the optimal cooperation of humans, machines and information technology (IT) systems. Thus, production technologies, production processes and organisation, as well as human resources development, are regarded as equally important within the concept (BMBF, 2015).

Most of the industrial policy initiatives in the countries studied have been initiated by national governments (Table 6); social partners have only been involved in initiating initiatives in two cases in Germany. It is also Germany where social partners in the manufacturing sector are deeply involved in the strategies and design of conditions for the future of manufacturing and the introduction of advanced manufacturing technologies.

However, social partners are involved in the management and governance of initiatives in other countries. In Italy,

Table 6: Major industrial policy initiatives addressing advanced manufacturing

Country	Year	Initiated by	Description	Industrial policy focus
Denmark	2010	Partnership of primarily enterprises, universities and technological institutes, but also Industriens Uddannelser (a joint social partner secretariat for vocational training within the field of industry covering apprenticeships)	**Danish Advanced Manufacturing Research Centre (DAMRC)** ○ Established using a grant from the Danish Industrial Foundation based on a fund set up by industry. ○ Promotes the manufacturing industry in Denmark, in particular to stop the loss of jobs by providing a framework for development and innovation. ○ Offers courses for vocational teachers on new technologies and production methods, mainly at higher education level.	○ Advanced manufacturing
	2012	Partnership of enterprises, universities, municipal development agencies and trade unions and a number of vocational schools offering apprenticeships of relevance in this field (for example, industrial technicians and CNC technicians)	**Manufacturing Academy of Denmark** ○ Helps the Danish manufacturing industry to implement new technology in their production within three focus areas: research; innovation; and education. ○ Organises meetings where state-of-the-art technologies and solutions are discussed by members (networking and knowledge sharing). ○ Funds research by more than 30 PhD students working closely with Danish companies to find new solutions to industry challenges. ○ Offers courses on new technologies and production methods, mainly at higher education level.	○ Machining technologies
	2017	Government	**Set up of knowledge centres** ○ Aims to stimulate the continued development of apprenticeships in Denmark in the context of rapid technological advance. ○ Ten knowledge centres were appointed among consortia of VET schools and other training providers in September 2017.	○ Automation and robotics ○ Process technology (PLC/ CPU steering and control) ○ Digital commerce ○ Databased service and business development
France	2013	Government	**Industrie du Futur (strategic plan for industry of the future)** ○ Investment programme designed to modernise France's industrial fabric. ○ Co-financed by the state through tax cuts and the public investment bank Oséo. ○ Aims to accompany industrial enterprises in their digital transition and to encourage the development of new innovative industrial sectors. ○ Has given new impetus to the competitiveness clusters (around 70) that gather together companies, research centres and schools to meet companies' new needs in terms of competencies and qualifications.	○ Digitalisation/ digital transition

Table 6: Continued

Country	Year	Initiated by	Description	Industrial policy focus
	2015	Government, various stakeholders	**Alliance Industrie du Futur** ○ This alliance of professional organisations from industry and digital technology along with academic and technological partners aims to put into practice the government's Industrie du Futur programme. ○ Seeks to promote the exchange of innovative practices and support to the transformation of business models,, new materials or advanced robotics.	○ Advanced manufacturing
Germany	2014	Government	**Innovation for Germany (new high-tech strategy)** ○ Fosters the transition towards Industry 4.0, focusing on research and innovation and the improvement of funding initiatives. ○ Supports scientific research in the implementation of advanced manufacturing through the revision of funding principles in order to make programmes more accessible, the creation of dialogue platforms reinforcing participation and the development of an open access strategy for publications. ○ Focuses on the impact on the labour market and different groups of workers in order to design framework conditions in the interest of enterprises and employees.	○ Digital economy and society, sustainable management and energy, innovation within the world of work, healthy living, smart mobility and civil security
	2013	Government, social partners	**Industry 4.0 (joint platform)** ○ Seeks to exchange good practice and experience, and to provide information on innovative projects and activities. ○ Provides information on new technological trends and best practice examples of enterprises implementing innovative technologies and processes.	○ New and innovative technologies/Industry 4.0 ○ Working groups, including on VET
	2014	Government, social partners	**Alliance for the Future of Industry (*Bündnis Zukunft Industrie*)** ○ Develops recommendations for action in the fields of rising the acceptance for industrial projects, the improvement of framework conditions for investments, the future of work in industry and industrial services, value creation structures of the future and the international competitiveness of German industry.	○ Industry and industrial services ○ Future of work, including dual apprenticeship

Ireland	2012	Government	**Making it in Ireland: Manufacturing 2020**
			○ Led to the study, *Future skills requirements of the manufacturing sector to 2020* (Forfás and Expert Group on Future Skills Needs, 2013).
			○ Formed part of preparations for the government's Action Plan for Jobs 2012.
			○ Sought to create a national step change by:
			  ○ enhancing productivity and competitiveness;
			  ○ improving connections to the customer and extending Ireland's international reach;
			  ○ broadening and deepening its innovative capabilities;
			  ○ strengthening collaborative actions for economic growth.
				○ Manufacturing

Table 6: Continued

Country	Year	Initiated by	Description	Industrial policy focus
Italy	2014	Public–private partnership	**Italian technology cluster Intelligent Factories (*Fabbrica Intelligente*)** ○ Supports technological development through the design and implementation of a series of research initiatives for the development of new enabling technologies: ○ preserving and cultivating in Italy advanced skills for manufacturing; ○ improving Italian companies' performance in attaining international funds; ○ increasing the return on investment of research projects; ○ supporting the entrepreneurship and the growth of companies thanks to the involvement of private investors; ○ strengthening national specialisation in robotics, new materials, advanced devices, virtual prototyping and applications of digital solutions in all manufacturing phases through, for example, the realisation of applied research projects, the sharing of knowledge, networking and research infrastructures.	○ Robotics, new materials, advanced devices, virtual prototyping and applications of digital solutions in all manufacturing phases
	2016	Government	**National Plan Industria 4.0** ○ Creates a favourable environment for Italian companies through a set of strategic and complementary measures to foster investment and innovation for the competitiveness of the national industrial system. ○ Offers support in terms of investment, the digitalisation of the production process, the growth of worker productivity, the training of relevant skills, and the development of new products and processes.	○ Manufacturing
Australia	2015–2016	Government	**Advanced Manufacturing Growth Centre and its Sector Competitiveness Plan 2016** ○ Aims to drive innovation in Australian manufacturing by fostering collaboration between industry enterprises and the scientific and research community. ○ The centre's specific activities are in addition to the general forms of assistance available to all companies (not just advanced manufacturing), such as tax benefits to companies undertaking R&D.	○ Advanced manufacturing
	2012	Regional government	**New South Wales Manufacturing Industry Action Plan** ○ Strategic plan for the New South Wales manufacturing sector until 2021, including recommendations on adjustment needs of education and training arising from digitalisation and advanced manufacturing.	○ Manufacturing

Table 6: Continued

Country	Year	Initiated by	Description	Industrial policy focus
USA	1988	Public–private partnership	**Manufacturing Extension Program (MEP)** ○ Improves the competitiveness of companies by accelerating the use of appropriate manufacturing technology by smaller US-based manufacturing companies. ○ This is a national system of 600 field locations in all 50 states and Puerto Rico. Each centre is a partnership between the federal government and a variety of public or private entities, including state, university and non-profit organisations. MEP centres offer expertise, needs assessment and training related to shop floor improvements. ○ Its cost–share model encourages centres to leverage resources and improve partnerships with other organisations and to emphasise services that are valued by manufacturers.	○ Manufacturing
	2011	Government	**Advanced Manufacturing Partnership (AMP)** ○ AMP is a government-coordinated platform of industries and research institutions aimed at increasing investment in emerging and advanced technologies such as IT, biotechnology and nanotechnology. ○ Its aim is to establish global leadership in next generation robotics, the energy efficiency of manufacturing processes and the development of new, cutting-edge technologies.	○ Manufacturing
	2015	Government	**National Strategic Computing Initiative** ○ Seeks to strengthen US leadership in high-performance computing by implementing a comprehensive research programme on future hardware technology.	○ Computing technologies

Note: *CPU = central processing unit; PLC = programmable logic controller.*
Source: *Country reports*

for example, the government set up a multi-stakeholder committee for Industria 4.0. This involves:

- government agencies (Presidency of the Council of Ministers, representatives of regional governments and various ministries[9]);
- leading Italian universities;
- Conference of the University Rectors;
- research centres (mainly National Research Council institutes);
- National Promotion Bank (*Cassa Depositi e Prestiti*);
- employer associations (Confindustria);
- trade unions – Italian Confederation of Labour (CGIL), Italian Confederation of Trade Unions (CISL), Union of Italian Workers (UIL), General Workers' Union (UGL).

In Denmark, two non-governmental organisations – the Danish Advanced Manufacturing Research Centre (DAMRC) and the Manufacturing Academy of Denmark (MADE) – have been set up, grouping enterprises with players from education, training and research, as well as social partners.

In addition, public–private partnerships have gained in importance. In Italy, for example, governance and awareness measures aim to generate interest in Industria 4.0 opportunities and create shared public–private governance. French industrial policy is also mostly built on public–private partnerships; its objective is to revive industrial innovation and to catch up in terms of high-tech productions (Gallois, 2012).

At regional level, advanced manufacturing is promoted via the creation of competitiveness clusters in France (*pôle de compétitivité*), technology clusters in Denmark (for example, Odense Robotics) and regional digital innovation hubs in Italy designed as multi-stakeholder networks (start-ups, research centres, industrial players, SMEs, universities, industrial clusters, investors, associations, government, incubators) with a backbone made up of Industria 4.0 competence centres to facilitate Industria 4.0 projects in all domains.

Financial and fiscal instruments designed to implement the measures for the promotion of advanced manufacturing are very important in the EU countries studied. In the USA, the idea of industrial policy is controversial. Although market-oriented economists and many political conservatives argue against 'picking winners' by favouring one industry over another (Ketels, 2007), subsidies to encourage small businesses and to stimulate economic growth in disadvantaged geographical areas are common (Subcommittee for Advanced Manufacturing of the National Science and Technology Council, 2016). Among the initiatives involving manufacturing are federal government investments in research, innovation and dissemination of good practice. Additional support for advanced manufacturing comes from government R&D spending, and an array of tax credits for R&D and for specific industries (Joint Committee on Taxation, 2015).

Employment and training challenges linked to technological change and automation

The introduction of advanced manufacturing techniques – the use of cutting-edge skills or technologies to generate efficiencies and improvements to production processes – will have major consequences for employment in the manufacturing sector.

> *This is likely to lead to new manufacturing methods which will require workers to develop skills that are primarily ICT-based in: digital techniques; computing; analytical thinking; machine ergonomics; understanding manufacturing methodologies (including design for manufacture, design for assembly and design for automation).*
>
> (Cedefop and IGF GHK, 2014, p. 3)

In all the countries studied, modern digital technologies and automation represent major drivers of change in terms of employment, skills needs or requirements in the manufacturing sector. Five major challenges for employment and training linked to technological change and automation were identified in the country reports:

- the substitution of jobs by machine work;
- new skills requirements;
- an increased need for certain occupations;
- a general lack of skilled labour;
- the capacity to adapt individuals and the system to constant changes.

Substitution of jobs by machine work

Concerns over the loss of jobs associated with automation are not new and go back decades. However, estimates of the extent of the substitution effect differ. In 2013, the widely discussed work of Frey and Osborne estimated the probability of computerisation for 702 detailed occupations in the USA by means of expert assessments and occupational activity structures. They asserted that a large share (47%) of professions as a whole in the US labour market faced the risk of becoming substituted by machine work ('computerisation') (Frey and Osborne, 2013, p. 12). In particular, jobs with middle qualification profiles (employees with an apprenticeship, technical vocational school or college qualification) will be at risk (Schmid et al, 2016).

These claims triggered similar research on the impact of digitalisation on work and future employment developments. However, recent studies on the employment effects of computerisation came to quite different estimates of the extent of substitution effects, depending on the methodological approaches adopted.

While studies based on the Frey and Osborne method of estimating the potential substitution of jobs calculated similar high shares of substitution effects (for example,

9 Ministry of Economy and Finance, Ministry of Economic Development, Ministry of Education, University and Research, Ministry of Labour and Social Policy, Ministry of Agriculture, Food and Forestry Products, Ministry of the Environment and Protection of Land and Sea.

in Germany; Bonin et al, 2015), a number of other studies adopted a different methodological approach based on tasks rather than jobs that could be substituted by computers and machines. Such studies come to much more modest results regarding gross effects (Dengler et al, 2014).[10] It should be noted that these figures are only describing gross effects that must be offset by new jobs created due to digitalisation-induced developments such as the emergence of new businesses, a growing demand for IT specialists and higher qualified professionals across all occupational fields (Dengler and Matthes, 2015).

A recent OECD report calculated the share of workers whose 'automatability' was at least 70%, defining them as workers at high risk (Arntz et al, 2016). In the countries studied here, the total share of workers at high risk ranges from 8% in Ireland and 9% in Denmark, France and the USA to 10% in Italy and 12% in Germany. While the shares of people with high automatability by level of educational attainment differ between countries, a common feature is that automatability is more pronounced for those who have completed primary education (International Standard Classification of Education 1, ISCED 1), lower secondary (ISCED 2) or upper secondary education (ISCED 3) than for those with higher education levels (ISCED 4 to 6) (Table 7).

A report published by the Committee for the Economic Development of Australia estimated that up to 40% of all jobs in Australia are at risk of being obsolete within 15 years (Durrant-White et al, 2015). The level of skills obsolescence has been calculated to be even higher for VET-trained occupations (Alpha Beta, 2015). However, Borland (2016) found no evidence that the current wave of automation had caused the total amount of work (as measured by the average hours of work per capita) to decrease. Although there has been a shift away from jobs that involve routine and manual tasks towards jobs that involve abstract tasks, the pace of this shift over the past 20 years is no greater than it has been since the mid-1960s, suggesting there is nothing special about the current automation process (Coelli and Borland, 2016).

In addition, a 2017 report by the McKinsey Global Institute drew the conclusion that there had been no overall job reduction in the USA, but plenty of shifts in jobs and displacement (Manyika et al, 2017). The report argued that technological change involves displacement but does not necessarily lead to high unemployment, since displaced workers can move to other jobs.

New skill requirements

Also, advanced manufacturing means that there is a need of both an adjustment of technical skillsets (for example, in the field of machine operators skills in relation to IT and electronics in combination with mechanical skills, engineering, technology and materials-related skills) as well as the acquisition of transversal skills and competences such as handling of abstract information, information gathering, problem solving, communication (including in English) and teamwork skills, and handling stressful situations (Abicht and Spöttl, 2012). In general, more interdisciplinary and cross-functional process know-how is needed as technologies change rapidly and production processes are becoming more complex and connected due to the introduction of new production technologies and processes.

Increased need for certain occupations

The digital transformation of the economy will create a need for highly skilled jobs (Mokyr et al, 2015; OECD, 2015).

A French study, for example, states that three groups of occupations will stand out with an estimated net creation of jobs between 2012 and 2022: the processing industry (+1%); industrial maintenance (+5%); and technical engineers (+16%). On top of these purely industrial professional families, employment needs for both computer scientists (+16%) and researchers (+18%) will be considerable (France Stratégie and DARES, 2015). In

Table 7: Share of people with high automatability (total and by level of educational attainment) (%)

Country	Share of people at high risk	Share of people with high automatability by level of educational attainment						
		ISCED 1	ISCED 2, 3C (short)	ISCED 3A-B-C (long)	ISCED 4A-B-C	ISCED 5B	ISCED 5A	ISCED 5A, 6
Denmark	9	33	41	10	0	2	1	0
France	9	41	29	13	n.a.	5	1	0
Germany	12	82	50	17	12	4	3	0
Ireland	8	0	42	19	13	5	0	0
Italy	10	40	32	11	0	n.a.	0	0
Australia	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
USA	9	100	44	19	8	6	1	0

Note: *n.a.= not available.*
Source: *Arntz et al (2016)*

10 The study calculated that 15% of dependent employees had a high substitution potential in 2013 because they were employed in occupations in which more than 70% of the tasks could already be substituted by computers.

addition, the CGIL believes there is a strong demand from enterprises for science and engineering professionals and technicians.

In Australia, the demand for high-skill occupations rose in the 10 years to 2013 by approximately 25,000 jobs. In addition, interviewed experts in Germany highlighted the fact that ICT skills have become more and more important across all sectors. This statement is backed by a European Commission study on e-skills demand and supply in Europe that estimates that there were 274,000 unfilled positions in 2012, representing 3.7% of the total of ICT professional jobs.[11] The study forecasts that the vacancy rate will reach over 10% by 2020 (Gareis et al, 2014).

General lack of skilled labour

Due to these new skills needs and a rising demand for employees in certain occupations, especially in the context of an increasing incidence of retirement, the lack of skilled labour is seen as an important barrier to growth in a worldwide market that is characterised by constant technological change. For example, given the technology-intensive nature of Danish manufacturing, the supply of competent labour is a vital condition for the continued success of industry, and players and stakeholders from across the board underline the fact that workers with the competences required for the exploitation of digitalisation, robotics and other technologies will be hard to find (Dansk Industri and Dansk Metal, 2016). In Ireland, the policy report *Future skills requirements of the manufacturing sector to 2020* highlighted the fact that

> *lean manufacturing techniques and increasing automation are driving upskilling requirements for both generic skills and technical skills across virtually all occupations.*

(Forfás and Expert Group on Future Skills Needs, 2013, p. 12)

Against this background of displacements and skills needs, the importance of education in determining employability is highlighted by several experts. In dealing with the displaced, Furman (2016) argued for job training, relocation assistance and occupational licensing reform. In Germany, various research studies and institutions (for example, Dengler et al, 2014; Acatech, 2016; BIBB, 2016a; German Council of Economic Experts, 2016) have stressed that one of the biggest challenges will be to foster vocational career possibilities and further qualification offers for employees with only low qualifications. Another challenge will be to adjust occupational profiles and VET programmes in general to match technological developments.

In principle, apprenticeships may reduce or contribute to the displacement associated with technical change. Unlike school-based programmes to develop skills, an apprenticeship ensures a relatively close match between current and expected future demands by employers and the content of vocational education and training. Apprentices learn on the most modern machines and learn the principles underlying their occupational tasks. Since most technological changes are evolutionary, well-trained apprentices can use their conceptual and practical skills to adjust to and sometimes even promote technological change.

As regards to the education and training related functions of apprenticeships, evidence from Germany suggests that apprentices experience training that is broad enough to transfer their skills across a wide range of occupations and that over two-thirds of former apprentices (including those who changed jobs) report using 'many' or 'very many' of the skills they learned as apprentices (Clark and Fahr, 2001). As regards the recruitment related function to apprenticeship labour market, experts (Hanushek, 2017) argued that apprenticeships in the USA will not be able to solve the main problem, which is not a shortage of skilled workers but a lack of workers who are able to adapt to new framework conditions. However, it should be noted that apprenticeships are very different in Germany and the USA. Consequently, the issue of limited mobility and obsolescence of skills in the USA may also arise because apprenticeships are not necessarily designed to equip workers with transferable skills.[12]

Capacity to adapt to constant changes

VET experts interviewed for this study highlighted the necessity of 'trainability' or the willingness for continuing, lifelong learning of individuals. Continuing technological, economic and societal changes require periodic updates of existing apprenticeship and training programmes, as well as the development of both new apprenticeships and new training opportunities enabling skilled workers at the various levels of qualifications to meet the requirements of a constantly changing working environment.

The primary challenge to be faced is linked to the capability of the national education and training system to radically renew settings, contents and methods (Teselli, 2016). New needs for qualifications and the skillsets of workers also have implications for learning and training methods and formats. As highlighted elsewhere (Acatech, 2016; Tornau, 2016), there is a need to supplement traditional face-to-face learning by new forms such as coaching techniques, learning by doing as well as self-learning.

National labour and training policies, however, do not always keep pace with industrial policy initiatives. For example, while the Italian Industria 4.0 plan and Smart Factory represent important industrial policy initiatives concerned with technological changes that are challenging mature technologies in the manufacturing sector, no action with a comparable scope has been undertaken within labour and training policies. Indeed, the Jobs Act of 2015, which reformed the labour market and changed the previous regulative framework of apprenticeship training, did not establish any mainstream connection with the challenges related to technological change and automation. In addition, according to stakeholders interviewed in the context of the national analysis, there is a lack of investment in improving the quality of training and in creating a link between IVET providers

11 Including management, business architecture and analysis level skills, ICT practitioners at professional level and at technician and associate level.
12 On differences between the USA and Germany in relation to the role of technology advancement and apprenticeships, Rendall and Weiss, 2016.

and local innovation systems. Furthermore, there are still important discrepancies between northern and southern regions, creating unequal opportunities for young people. Good practices regarding higher apprenticeship in the manufacturing sector are emerging in university–industry partnerships in northern Italy (with the support of regional administrations). Some of these examples of such partnerships are the master's postgraduate courses at the Politecnico of Turin,[13] the Politecnico of Milan[14] and the Motor Vehicle University of Emilia-Romagna, bringing together five universities in that region.[15]

In the USA, an array of small-scale programmes has been undertaken to deal with the implications of technical change for the workforce (for example, by sponsoring industry–school collaborations). However, these programmes concern only a modest share of the workforce. The main government-funded programmes for training or retraining workers to prepare for specific careers are postsecondary college programmes with a technical/occupational focus and the federally funded, locally delivered workforce programmes under the Workforce Innovation and Opportunity Act. Although these programmes offer information and job placement services to about five million workers, only about 200,000 have received occupational training (Besharov, 2017). Several other federal training programmes, including Job Corps, YouthBuild and Trade Adjustment Assistance, offer training to an additional 80,000 workers.

A larger source of career-focused education and training is the system of community and private career colleges. Over 60% of the students in these colleges are taking occupational courses. Most of these are not working in a related job and thus spend no time in a company while doing occupational courses. They pay their own tuition fees, though at rates subsidised by the state and local government to the institutions, and/or with federal grants to students based on their family incomes. Those taking manufacturing-related programmes represent only about 6% of students. However, students in these majors represent about 5% of the number employed in manufacturing.

In contrast, Industrie 4.0 in Germany has been closely linked from the beginning to the labour market as well as to VET policies (BMBF, 2010). The employment and VET dimension of Industrie 4.0 and the digitalisation of the economy as a whole have become more significant in recent years and today Arbeit 4.0 (Work 4.0) and Berufsbildung 4.0 (Vocational Training 4.0) (BIBB, 2016a) have become synonyms of the need to make comprehensive adjustments to the regulation and public policies in both areas. In spring 2015, the Federal Ministry for Labour and Social Affairs (BMAS) launched a broad stakeholder debate involving political parties, social partners, and research and academic institutions, as well as civil society organisations, on the future of work or Work 4.0. This led to the publication of a green paper (BMAS, 2015), a white paper (BMAS, 2016a), three workbooks (BMAS, 2016b, 2016c, 2017), and the promotion of learning and experimentation regarding digitalisation funded by a funding guideline.[16]

13 See https://didattica.polito.it/master/home/en/advanced_education_and_research_apprenticeship for more information.
14 See http://www.mip.polimi.it/en/academics/people-and-careers/masters/ for more information.
15 See https://motorvehicleuniversity.com/en/ for more information.
16 See http://www.bmas.de/DE/Schwerpunkte/Arbeiten-vier-null/arbeiten-vier-null.html for more information.

2 Overview of apprenticeship systems

Varieties of apprenticeship systems and practices

Common principles and orientations at EU and global level

At EU level, numerous proposals have been made more recently to promote apprenticeship training. As regards to the applicability of these proposals, it is important to note that neither at EU nor international level is there a shared definition of apprenticeship.

In April 2013, the European Council agreed on a Recommendation that established a Youth Guarantee intended to ensure that

> *all young people under the age of 25 years receive a good-quality offer of employment, continued education, an apprenticeship or a traineeship within a period of four months of becoming unemployed or leaving formal education.*

(Council of the European Union, 2013b, Recommendation 1)

This was supported financially by the Youth Employment Initiative with a budget of €6.4 billion for the period 2014 to 2020, which was later increased to €8.4 billion (European Council, 2013).

In July 2013, the European Alliance for Apprenticeships[17] was launched on the basis of a declaration signed by the Presidency of the European Union, the European Commission and European social partners – namely the European Trade Union Confederation (ETUC), BusinessEurope, the European Association of Craft, Small and Medium-sized Enterprises (UEAPME) and the European Centre of Employers and Enterprises providing Public Services (CEEP). They committed themselves

> *to contribute to the access to, supply, quality and attractiveness of apprenticeships across the EU by encouraging the setting up, reviving or modernising of apprenticeship schemes ...*

(ETUC et al, 2013)

These schemes were to be built on the basis of the following principles (European Commission, 2017b):

- effective partnerships between education and training institutions and enterprises;
- involvement of social partners, and, as appropriate, intermediary bodies in the governance of apprenticeship systems;
- high quality of the qualifications and learning process integration of apprenticeship schemes into national/regional education and training systems;
- a clear regulatory framework, clarifying the responsibilities, rights and obligations of each party involved.

In October 2013, the Council of the European Union adopted a declaration on the European Alliance for Apprenticeships (see Box 1). It concluded that

> *high-quality apprenticeship schemes can make a positive contribution to combating youth unemployment by fostering skills acquisition and securing smooth and sustainable transitions from the education and training system to the labour market. Such schemes are particularly effective when embedded in a comprehensive approach at national level that combines education, training and employment measures.*

(Council of the European Union, 2013a, p. 2)

For its part, the European Commission set up a Working Group on Vocational Education and Training, whose focus was to assist EU Member States in their work of furthering policy development on VET through mutual learning and the identification of good practice. The Working Group concluded its first phase of activities with the publication of a booklet defining 20 guiding principles clustered into four different priority areas (European Commission, 2015b):

- national governance and social partner involvement;
- support for enterprises, in particular SMEs, offering apprenticeships;
- attractiveness of apprenticeships and improved career guidance;
- quality assurance in work-based learning.

However, these guiding principles did not refer to or correspond to those agreed by the Council of the European Union.

In April 2016, ETUC published the report *A European quality framework for apprenticeships – A European trade union proposal* for the trade union side (ETUC, 2016), while on the employers' side, BusinessEurope, UEAPME and CEEP published *The cost-effectiveness of apprenticeship schemes – Making the case for apprenticeship* (BusinessEurope et al, 2016). On the basis of these two

17 To date, 36 countries have made national commitments under the Alliance, including 27 EU Member States (bar the UK), all five candidate countries and all four EFTA countries. Liechtenstein recently joined the EAfA as the last EFTA country in February 2018. Also, 236 pledges have been made by various apprenticeship stakeholders. Since 2013, companies, employers and intermediaries have pledged to provide over 860,000 apprenticeship and other training or first-job opportunities to young people.

Box 1: Declaration on the European Alliance for Apprenticeships

The declaration sets out the following guiding principles in relation to the effectiveness and attractiveness of apprenticeship schemes:

- establishing an appropriate regulatory framework, whereby the responsibilities, rights and obligations of each party involved are clearly formulated and are enforceable;
- encouraging national partnerships with social partners in the design, implementation and governance of apprenticeship schemes, together with other relevant stakeholders such as, where appropriate, intermediary bodies (chambers of commerce, industries and crafts, professional and sectoral organisations), education and training providers, youth and student organisations, and local, regional as well as national authorities;
- ensuring adequate integration of the apprenticeship schemes into the formal education and training system through a system of recognised qualifications and competences which may allow access to higher education and lifelong learning;
- ensuring that the qualifications and competences gained and the learning process of apprenticeships are of high quality with defined standards for learning outcomes and quality assurance, in line with the recommendation on the establishment of a European Quality Assurance Reference Framework for VET, and that the apprenticeship model is recognised as a valuable learning tool, transferable across borders, opening up the route to progress within national qualifications frameworks and aspiration to high-skilled jobs;
- including a strong work-based, high-quality learning and training component, which should complement the specific on-the-job skills with broader, transversal and transferable skills, ensuring that participants can adapt to change after finishing the apprenticeship;
- involving both employers and public authorities sufficiently in the funding of apprenticeship schemes, while ensuring adequate remuneration and social protection of apprentices, and providing appropriate incentives for all players to participate, especially SMEs, and for an adequate supply of apprenticeship places to be made available;
- covering multiple sectors and occupations, including new and innovative sectors with a high employment potential, and taking into account forecasts of future skills needs;
- facilitating the participation of young people with fewer opportunities by providing career guidance, preparatory training and other targeted support;
- promoting apprenticeship schemes through awareness raising targeted at young people, their parents, education and training providers, employers and public employment services, while highlighting apprenticeships as a pathway leading to excellence which opens up broad educational and professional opportunities, including apprenticeships as one of the options for the implementation of the Youth Guarantee schemes.

Source: *Council of the European Union (2013a)*

studies, the social partners agreed a joint statement, *Towards a shared vision of apprenticeships* (ETUC et al, 2016).

In December 2016, together with government representatives within the Advisory Committee of Vocation Training, the social partners agreed *A shared vision for quality and effective apprenticeships and work-based learning* (Advisory Committee on Vocation Training, 2016). Other key policy initiatives launched in 2016 that paved the way to a further boost of apprenticeships at EU level were the New Skills Agenda for Europe and Investing in Europe's Youth, with its emphasis on high-quality apprenticeships. One of the 10 key actions of the New Skills Agenda for Europe is the 'blueprint for sectorial cooperation', which serves as an action plan for strategic cooperation on skills, including VET and higher VET, at sectoral level involving representatives from industry, education and training, as well as employment. This is a complementary building block of EU industrial policy; the objective is to establish European-level partnerships whereby sector stakeholders develop skills, strategies and solutions to support growth and competitiveness in their respective fields.

The Investing in Europe's Youth initiative has a different focus and it is intended to support young people in acquiring relevant skills and gaining better employment and learning opportunities, while matching an increasing awareness of and interest in apprenticeships as an effective measure to facilitate the transition from education and training into the labour market.

It was precisely in the context of the New Skills Agenda for Europe that the European Commission adopted in October 2017 the proposal for a European Framework for Quality and Effective Apprenticeships (EFQEA). This is linked with the European Pillar of Social Rights, which reaffirms the right of everyone to high-quality and inclusive education, training and lifelong learning.

The specific objective of the proposal would be to provide a coherent framework based on a common understanding

of what defines quality and effective apprenticeships, taking into account the diversity of VET systems in EU Member States (European Commission, 2017c). It is proposed that the following issues could be addressed:

- criteria for quality and effective apprenticeships, which would include a written agreement;
- learning outcomes;
- pedagogical support;
- workplace component;
- pay and/or compensation;
- social protection and work, health and safety conditions;
- criteria for the framework which would include the regulatory framework, the involvement of social partners, support for companies, flexible pathways and mobility, career guidance and awareness raising, transparency, and quality assurance and tracking on apprentices.

The European Commission's proposal for a European Framework for Quality and Effective Apprenticeships is in line with the guiding principles of the European Alliance for Apprenticeships. It also supplements the 20 quality standards formulated by ETUC and the related quality criteria to measure their implementation. The aim is to ensure that apprenticeship schemes contribute to the specific needs and requirements of both learners and employers by stipulating a number of criteria around two complementary dimensions:

- from one side, at company or local and sectoral level, the learning and working conditions;
- from the other side, at more institutional level, the overall framework conditions.

The Commission's proposal was adopted by the Council in March 2018, but introduced some changes, in particular in relation to the definition of apprenticeships. According to the adopted recommendation, apprenticeships should be based on 'a written agreement defining the rights and obligations of the apprentice, the employer and, where appropriate, the vocational education and training institution' and 'pay and compensation should be in line with national or sectoral requirements or collective agreements where they exist, and taking into account arrangements on cost-sharing between employers and public authorities' (Council of the European Union, 2017, pp. 8–9). In addition, there is now a reference to the 'further training needs of VET teachers and trainers regarding digital innovations in apprenticeships' (p. 12).

If it is difficult to settle on a definition at European level, it can be imagined that the task is considerably greater at the global level. Indeed, there is no current definition of apprenticeship training. However, in a detailed and wide-ranging recommendation, the Vocational Training Recommendation, 1962 (No. 117), the ILO put forward the following definition:

> *Systematic long-term training for a recognized occupation taking place substantially within an undertaking or under an independent craftsman should be governed by a written contract of apprenticeship and be subject to established standards.*
>
> (ILO, 1962)

It went on to specify a series of requirements for apprenticeship training, notably, the conditions necessary for occupations to be recognised as 'apprenticeable' and 'the content of apprentices' contracts. It also enumerated matters in the standards and regulations governing apprenticeships that should be considered for each recognised 'apprenticeable' occupation. It also covered the need for comprehensive health and safety training for apprentices and the importance of pre-entry vocational guidance (ILO, 1962).

However, the Vocational Training Recommendation made no specific reference to off-the-job training. More importantly, it was superseded by the Human Resources Development Recommendation, 2004 (No. 195), which makes no specific mention of apprenticeship training (ILO, 2004).

Elsewhere, at the global level, the Labour and Employment Ministers of the G20 – the central forum for international cooperation on financial and economic issues which is composed of 19 countries plus the EU – called on their members in 2012 to

> *foster sharing of experience in the design and implementation of apprenticeship programmes and explore ways to identify common principles across the G20 countries …*
>
> (G20 Labour and Employment Ministers, 2012, p. 6)

Four years later, they reiterated their call for action on apprenticeships and adopted the G20 Initiative to Promote Quality Apprenticeship, acknowledging that

> *apprenticeship has proven to be an increasingly useful method to deliver vocational training globally.*
>
> (G20 Labour and Employment Ministers, 2016, p. 12)

The social partners – the trade unions (Labour 20, L20) and employer associations (Business 20, B20) – of the G20 Member States also joined forces to promote apprenticeships. They agreed on the Key Elements for Quality Apprenticeships in 2013 and reiterated their commitment to promoting Quality Apprenticeships in the 'B20–L20 Ankara Declaration' in 2015.

In 2013, global trade unions and employer associations – the International Trade Union Confederation (ITUC), the International Organisation of Employers (IOE), the Business and Industry Advisory Committee to the OCED (BIAC) and the Trade Union Advisory Committee to the OECD (TUAC) – also jointly emphasised a number of key principles for making apprenticeships work (see Box 2).

The issue of high-quality apprenticeships is still on the agenda, and at its Governing Board meeting in March 2017, the ILO had an initial discussion on the possibility of setting an International Labour Standard for apprenticeships.

Working definition of apprenticeship in the country sample

As explained in the Introduction to this report, the working definition of apprenticeship provided by Cedefop is used

Box 2: Key elements of quality apprenticeship as defined by ITUC, IOE, BIAC and TUAC

The global social partners have defined the following key elements that should characterise 'quality apprenticeship':

- there must be a shared responsibility between governments, employers and trade unions adequate to national circumstances;
- high-quality vocational schools, with highly qualified and motivated teachers and up-to-date equipment are an indispensable prerequisite for effective learning;
- effective entries into apprenticeships should be available, not only for young people, but also displaced adults who either need to move into a new industry or need to update their skills for the evolving needs of business;
- strategies for lifting the status of quality apprenticeships should be developed so that they are positively seen as a pathway towards a satisfying career;
- quality apprenticeship systems need their own contractual arrangements consistent with national law and practice;
- quality apprenticeship systems must be workplace centred;
- quality apprenticeship programmes should reflect gender equity objectives;
- quality apprenticeships should encourage entrepreneurship and innovation through the development of skills and general business knowledge as well as responsible business conduct.

Source: *Council of the European Union (2013a)*

as a reference in the seven country reports and in this comparative report.

Part of the features of some apprenticeship schemes in Denmark, France, Germany, Ireland and Italy correspond to the Cedefop definition (Table 8). The training is 'systematic' and based upon occupational and educational standards that have been decided by public authorities in partnership with social partners and VET providers. The training is generally long term, ranging from three to six years in Denmark, two to three and a half years in Germany, normally four years in Ireland, and one to four years in Italy. The exception is France, where six-months apprenticeships exist.

Apprenticeships in all the five Member States generally take place in two training locations – the enterprise and the VET institution, with a clear majority of time spent on the job. All apprenticeships are based on a written contract signed by the employer of the host enterprise and the apprentice (or their legal representatives). Apprentices in all the five Member States receive remuneration. The employers assume responsibility for providing the company-based part of the training programme, with off-the-job training provided by VET institutions. Successful completion of an apprenticeship leads to the award of a nationally recognised qualification. In four of the countries, the qualification is recognised nationally; in Italy, the qualification for the Level II professional apprenticeship is recognised by the social partners. For this type of apprenticeship, there are no educational standards linking the occupational profiles covered by it, with the system of educational qualifications recognised at national (and European) level.

In Denmark and Germany, apprenticeships – though often different one from another – belong more or less to the same specific and recognisable form of initial VET.

In France, however, there are two types of apprenticeship within the '*alternance*' system. These are regulated differently, either in terms of an apprenticeship contract (*contrat d'apprentissage*) or through a professionalisation contract (*contrat de professionalisation*). The former is the most prevalent.

Table 8: Correspondence between the Cedefop definition of an apprenticeship and the situation in the five EU Member States

	Denmark	France	Germany	Ireland	Italy
Systematic	Yes	Yes	Yes	Yes	Yes
Long-term	3–6 years	0.5–3 years	2–3.5 years	4 years	1–5 years
Alternating	Yes	Yes	Yes	Yes	Yes
Contract	Yes	Yes	Yes	Yes	Yes
Remuneration	Yes	Yes	Yes	Yes	Yes
Employer responsibility	Yes	Yes	Yes	Yes	Yes
Qualification	Yes	Yes	Yes	Yes	Yes, for Level I and III

Source: *Country reports*

In Italy, there are three types or levels of apprenticeship, which are regulated differently:

- Level I apprenticeship or apprenticeship for acquiring a vocational qualification or diploma (*apprendistato per la qualifica e il diploma professionale, il diploma di istruzione secondaria superiore e il certificato di specializzazione tecnica superiore*);
- Level II apprenticeship or professional apprenticeship (*apprendistato professionalizzante*);
- Level III apprenticeship or higher education and research apprenticeship (*apprendistato di alta formazione e ricerca*).

The professional apprenticeship is by far the most prevalent (95.1% of all apprenticeships in 2015).

In Ireland, there are 27 designated craft apprenticeships, plus new apprenticeships that have emerged following the review of apprenticeship training in Ireland (Ministry for Education and Skills, 2013).

Australia has 'apprenticeships' and 'traineeships', which may be similar, depending on the states or territories involved. In the USA, there are two categories – registered and unregistered – and different sets of regulatory provisions, which can lead to radically different forms of IVET between states. Moreover, there is no mandatory requirement to register an apprenticeship programme, and an employer can still run an apprenticeship programme without formal approval. In addition, there is a specific apprenticeship initiative run by the United Services Military Apprenticeship Program (USMAP) for active duty Navy, Marine Corps and Coast Guard service members.

Regulatory framework and institutional context

The regulatory framework for each country is complex and made up of a patchwork of different legal texts, agreements and practices, depending on the historical development of apprenticeships over the years. Typically, this framework has the following eight different functions:

> *(i) spells out the main training and skills development requirements in order to ensure the learning content and quality of the programme;*
>
> *(ii) provides a clear outline of the rights, roles and responsibilities of all relevant parties and, in some cases, institutionalises the specific role of key actors, notably social partners;*
>
> *(iii) specifies the status of apprentice/trainee;*
>
> *(iv) outlines the basic apprentice/trainee-related terms and conditions, including (where applicable) entitlement to remuneration and other benefits;*
>
> *(v) determines the (minimum) duration of the placement as well as the distribution of time between school- and work-based training;*
>
> *(vi) specifies quality assurance mechanisms;*
>
> *(vii) defines the contractual arrangements between the educational institution, employer and apprentice, usually reflected in an apprenticeship/traineeship agreement;*
>
> *(viii) sets the minimum qualifications and length of previous professional experience for trainers both at the educational institutions and within the companies.*
>
> (European Commission, 2013b, p. 12)

These functions are never to be found in one single document. The basis of the regulatory framework for apprenticeship training in the five EU Member States and two non-EU countries studied is primary legislation, whether at the state and territorial level in Australia or at national level in all the other countries:

- Denmark – Vocational Education and Training Act;
- France – Vocational Training, Employment and Social Democracy Law;
- Germany – Vocational Training Act;
- Ireland – Industrial Training Act (and subsequent reforms);
- Italy – Jobs Act (Legislative Decree 81/2015);
- USA – Fitzgerald Act.

Secondary legislation is used to implement the primary legislation, for example, government orders in Denmark, decrees in France and Department of Labor regulations in the USA.

In addition, a variety of different legislation impinges on the implementation of apprenticeship training:

- laws on funding (Denmark, France, Ireland and Italy);
- laws on administrative structures (Ireland);
- laws on quality and qualifications (Australia, Ireland and Italy).

Where these laws emanate from different ministries (for example, for social affairs or education), the coordination and coherence of the national apprenticeship system can be a concern.

In EU Member States where the implementation of education and training policy falls under the legal competence of the regions (France and Italy), or the federal states (Germany and the USA), or the states and territories (Australia), there is a further layer of regulation and a further concern regarding the coordination and coherence of the national apprenticeship system. To ensure the quality of qualifications and the recognition of apprenticeship qualifications throughout the entire country, regions often coordinate – or attempt to coordinate – under a national umbrella, for example:

- Germany – Federal–Länder Coordination Committee for Vocational Training Regulations;
- Italy – Technical Body[18], the Steering Group dedicated to alternance, the Monitoring, the Evaluation Committee on alternance and the State–Regions Conference;
- Australia – Industry Reference Committees.

18 Composed of representatives from the Ministry of Labour and Social Policies, the Ministry of Education, universities and research institutions, the State–Regions Conference, social partners and the National Institute for the Analysis of Public Policy (INAPP).

The regulatory framework also includes decisions taken at sectoral level by the social partners, either alone or with the public authorities, as a result of consultation within sectoral skills councils or as a result of collective bargaining.

At the enterprise level, the contract signed between the employer and the apprentice also form part of the regulatory framework with, in addition, training institutions in certain cases. The provisions to be found in the contract are generally stipulated in the primary legislation. For example, in Germany, the contract, as stipulated in the German Vocational Training Act, should contain the following:

- the nature, syllabus, timetable and purpose of the initial training, and in particular the form of occupational activity for which initial training is to be provided;
- the commencement date and duration of the initial training;
- any initial training measures taking place outside the training premises;
- the length of the normal daily hours of initial training;
- the length of the probationary period;
- the payment of an allowance and the rate to be applied;
- the amount of holiday leave;
- the conditions under which the initial training contract may be terminated;
- a general reference to collective agreements, plant agreements or service agreements applicable to the initial training relationship.

Financing the apprenticeship system

Apprenticeship funding arrangements vary considerably (see Table 9), but the most commonly observed pattern of cost distribution is as follows.

Public authorities – whether nationally, regionally or locally – finance off-the-job training in VET institutions, the administration of the scheme and incentives for employers (where these exist). In some Member States (Denmark, France, Ireland and Italy), employers contribute to these costs via a levy or an apprenticeship tax.

The costs of on-the-job training are borne by the employer with, on occasion, certain incentives provided by different representatives of the public authorities. The employer also bears the cost of wages/allowances and social security contributions.

Table 9: Financing for off- and on-the-job training, and incentives to support apprenticeship training

Country	Off-the-job training	On-the-job training	Incentives
Denmark	National government	Employer	Funding for wages during the off-the-job training from the Employers Reimbursement Fund
France	National government, regions, bipartite interprofessional funds	Employer	Recruitment premiums for employers that are set by the regional governments and which support in particular smaller companies with fewer than 11 employees Tax exemptions and lower social security contributions Funding for training for disadvantaged younger people (for example, persons with a disability)
Germany	National government, federal states, municipalities	Employer	Funding for wages during the on-the-job training for disadvantaged younger people (for example, persons with a disability)
Ireland	National government	Employer	Funding for wages during the off-the-job training for designated trade apprenticeships from the National Training Fund and for underrepresented groups (for example, women)
Italy	Regions, national government*	Employer, bipartite interprofessional funds	Funding for the on-the-job training for professional apprenticeships* Tax exemptions and lower social security contributions for the on-the-job training
Australia	States, territories	Employer	Funding for on-the-job training for priority occupations, regions and underrepresented groups (indigenous Australians, mature apprentices and apprentices with a disability) Subsidies for off-the-job training
USA	Employer	Employer	Some states offer small tax credits Publicly supported community colleges offer low tuition fees and sometimes discounts for apprenticeship

Note: * *Funding from employers/bipartite funds is not only for apprenticeships.*

Apprentices generally receive lower levels of remuneration than they might possibly obtain in other jobs, but clearly more than students in VET institutions and universities.

In all five EU Member States and also Australia, off-the-job training in VET institutions is financed by the public authorities. In Germany, for example, the supervision of schools, the training and salaries of teachers, and the definition of teaching plans are funded by the federal states, while the construction, maintenance and renovation of school buildings is funded by the municipalities. In France, the national government, regions and the public employment services fund off-the-job training. In Australia and Italy, off-the-job training is funded by the states and territories or the regions, respectively. In Denmark and Ireland, it is funded by the national government. The exception to this pattern is provided by the USA, where off-the-job training is generally funded by the employer, or by the employer and trade union (for example, in the construction industry).

Employers in all the five EU Member States and the two non-EU countries pay for the time of in-company mentors, and the wages and social contributions of the apprentices during both on- and off-the-job periods. In Denmark, France, Ireland and Italy, they also contribute to the overall funding of the apprenticeship programmes via a levy or an apprenticeship tax. In Denmark, all employers with more than four employees, whether they employ apprentices or not, are required to contribute to the Employers' Reimbursement Fund. In France, employers pay an apprenticeship tax (*Taxe d'apprentissage*) equivalent to 0.68% of the wage bill.[19] In Ireland, employers contribute to the National Training Fund, which pays for the operation of the entire apprenticeship system.

At the same time, public authorities in all five EU Member States provide incentives – to a greater or lesser degree – to encourage employers to take on apprentices. In France, employers receive a recruitment premium, employers in Denmark receive funds from the Employers' Reimbursement Fund and those in Ireland from the National Training Fund to cover the wage costs of apprentices while they are engaged in off-the-job training. In Italy, employers can obtain funding for on-the-job training for professional apprenticeships from bipartite interprofessional funds; in addition, they benefit from tax exemptions for the on-the-job training and lower social security contributions for their apprentices. Employers in some countries can also obtain limited funding for underrepresented groups, such as female participants in Ireland and young people with a disability in Germany.

In the non-EU countries, Australia has a well-developed system of incentives for employers to take on apprentices for priority occupations (for example, care workers or nurses), for underrepresented groups (indigenous Australians, mature apprentices and apprentices with a disability) and for regional development purposes. Some US states may provide some form of tax credits.

Apprentices receive lower levels of remuneration than skilled workers, often calculated as a percentage of a skilled worker's wage. Apprentices in all the five EU Member States receive remuneration, either as a result of collective bargaining at the sectoral level (Denmark, Germany, Ireland and Italy) or on the basis of the labour code (France); pay increases as the apprentices advance though their training. In the non-EU countries, the minimum rate for an apprentice in Australia varies depending on the sector and the duration of the apprenticeship. In Australia and the USA, pay also increases as the apprentices advance through their training.

Key players and their governance role

One of the significant features of apprenticeship systems is the inclusion of a broad range of key players in policymaking and implementation at all levels (Table 10).

The overall responsibility for designing and developing apprenticeship training in most EU Member States lies with a national ministry, and in Italy with two:

- Denmark – Ministry of Education;
- France – Ministry of Education;
- Germany – Ministry of Education and Research;
- Ireland – Department of Education and Skills;
- Italy – Ministry of Labour and Social Policies and Ministry of Education, research and Industry.

In the non-EU countries, the apprenticeship training policy in Australia is coordinated through the Industry and Skills Council, which is part of the Council of Australian Government's framework. There is no process for developing national or state occupational standards for apprenticeships in the USA, but the Office of Apprenticeship oversees the apprenticeship registration process, records information on apprentices and issues completion certificates.

At national level, four EU Member States have bodies with social partner involvement and, on occasion, representatives from the regions and training providers, who are consulted on matters related to VET and apprenticeship training:

- Denmark – National Council of Vocational Education and Training;
- France – National Council for Employment, Training and Vocational Guidance (CNEFOP);
- Germany – Board of the Federal Institute for Vocational Education and Training (BIBB);
- Ireland – Apprenticeship Council (for 'new' apprenticeships) and the National Apprenticeships Advisory Committee (for designated trade apprenticeships) supported by SOLAS.

In Australia, employers are represented on the Australian Industry and Skills Committee which reports to the Industry and Skills Council, but trade unions are not.

19 In addition, companies with more than 250 employees and a share of apprentices of less than 5% have to make a supplementary contribution. The exact amount depends on the precise company rate (see https://www.service-public.fr/professionnels-entreprises/vosdroits/F22574).

Table 10: Key players at national, sectoral and regional/local levels

Country	National	Sectoral (at national, regional and/or local level)	Regional/local
Denmark	Ministry of Education National Council of Vocational Education and Training	Trade committees	Local trade committees
France	Ministry of Education National Council for Employment, Training and Vocational Guidance	Consultative vocational committees Prospective observatories for occupations Qualifications approved bipartite collection bodies	Regional Council for Employment, Training and Vocational Guidance
Germany	Federal Ministry of Education and Research Board of the Federal Institute for Vocational Education and Training	Social partners	Chambers of Commerce and Industry Chambers of Crafts and Trades
Ireland	Department of Education and Skills Apprenticeship Council National Apprenticeships Advisory Committee SOLAS (state agency)	There are no sector skills councils but some social partner organisations are involved	Education and Training Boards
Italy	Ministry of Labour and Social Policies Ministry of Education, University and Research State–Regions Conference	Social partners Bipartite interprofessional funds	Regions Accredited VET institutions
Australia	Industry and Skills Council	Group training organisations	Group training organisations
USA	Office of Apprenticeship, US Department of Labor	Joint union–management apprenticeship committees National trade unions in commercial and industrial construction	State apprenticeship agencies in some states State and local workforce boards are increasingly involved in apprenticeship

Source: *Country reports*

It is at the sectoral level that social partner involvement is at its most influential in the EU Member States. Social partners are consulted on matters relating to apprenticeship training in four EU Member States.

- In Denmark, this is via around 50 local trade committees.
- In France, there are seven consultative vocational committees linked to the Ministry of Employment and 14 linked to the Ministry of Education. In addition, there are 126 prospective observatories for occupations and qualifications, and their approved bipartite collection bodies, which provide funding for apprenticeship training.
- In Germany, social partner discussions jointly define the requirements for quality standards. The social partners may also negotiate collective bargaining agreements, parts of which may deal with apprenticeship issues.
- In Italy, social partners are responsible for negotiating sectoral collective agreements which include specific articles dedicated to Level II apprenticeship issues.

In Australia, trade unions generally play no formal role in apprenticeship training policymaking or implementation at the sectoral level. In the USA, in rare cases (for example, in the construction industry and electrical trades), Joint Apprenticeship Committees made up of employer and trade union representatives organise an occupational programme for several companies and provide apprenticeship places.

At the sectoral and also regional level in Australia, Group Training Organisations play a significant role. They are not-for-profit entities that employ apprentices and trainees directly and place them with host employers. They recruit, select and pay apprentices as well as oversee the quality of the on-the-job training.

There is a role for regional bodies in the four EU Member States too. In France, the Regional National Council for Employment, Training and Vocational Guidance, with social partner involvement, is responsible for:

- determining the number of apprenticeship training places on the basis of local objectives;
- financing and supervising the apprenticeship training centres.

At the regional/local level in Denmark, each vocational school has a local trade committee, which is responsible for any necessary adaptations of national standards to the local training curriculum. These local trade committees – consisting of employer and trade union representatives in equal numbers – are the awarding bodies and are responsible for assessing apprentices in their final trade worker's test.

In Germany, local Chambers of Commerce and Industry or Crafts and Trades Chambers have a key role to play;

- advising enterprises on IVET.
- training in-company mentors.
- assessing and certify in-company training provision.
- monitoring in-company training (facilities, instructors and so on).
- supporting enterprises in finding candidates for apprenticeship training.
- registering training contracts.
- organising mid-term and final assessments.
- mediating disputes between apprentices and enterprises.

In Ireland, a key role is played by Education and Training Boards at the local level.

At the enterprise level, in Germany for example, social partners plan and implement company-level training and its contents based on company-specific needs. The works council plays an important role in this context, and in companies with at least five apprentices, it has the legal right to elect an apprenticeship spokesperson.[20]

And then there are the VET institutions themselves. In Denmark, for example, the boards of governors of VET institutions are composed of representatives of the social partners, regional authorities, staff and VET learners, although the social partners usually represent the majority of members. This means that the social partners not only have a decisive influence on standards, examinations and curricula, but also on the delivery of the VET programmes.

The enterprises are of course key players – if they do not participate actively then there is no apprenticeship system. In Germany, for example, enterprises are required to engage in-company mentors who liaise with training consultants from the chambers of commerce, teachers and trainers from the VET institutions, so that apprentices can acquire the knowledge and skills laid down in the training plan. In addition to the preparation and implementation of the training, the enterprises contribute to the assessment of the performance of the apprentices.

Finally, there are the apprentices themselves who go through the whole process. Increasingly, public authorities in all the countries studied are making a particular effort to bring their responsibilities to the attention of future apprentices.[21] In general, apprentices are required to:

- be ready to learn and work;
- engage fully and take on responsibilities gradually as their training progresses;
- follow safety instructions carefully;
- protect the equipment and facilities of the enterprise;
- build up a good working relationship with both in-company mentors and with teachers and trainers in VET institutions.

Selected national data and trends

It has to be noted that because of the different national systems and understandings of what an apprenticeship is, it is not possible to compare statistical data. Thus, the following paragraphs focus on national data and trends over time. As far as the five EU Member States are concerned, there is a mixed picture in terms of the number of apprenticeships in the period 2008 to 2015 (Table 11).

Table 11: Number of apprenticeships 2008–2015

	2008	2009	2010	2011	2012	2013	2014	2015
Denmark	58,528	60,251	63,220	61,451	60,315	59,851	59,114	51,011
France	–*	434,531	449,027	476,622	492,940	462,777	456,198	469,380
Germany	616,342	564,300	560,000	569,400	551,300	529,500	523,200	522,200
Ireland	23,092	15,024	10,171	8,328	6,223	5,711	6,913	8,317
Italy	645,594	594,668	528,183	492,492	470,056	452,731	446,227	410,213
Australia	433,800	423,800	436,900	459,200	515,200	404,500	346,700	306,700
USA	442,386	420,140	387,720	357,692	362,123	375,425	410,375	447,929

Note: * *No comparable figures for 2008 due to a change in the data collection methodology for professionalisation contract apprentices.*
Source: *Country reports*

20 According to Article 60 of the German Works Constitution Law (*Betriebsverfassungsgesetz*), the size of the apprenticeship representation varies between one spokesperson (in enterprises with at least five apprentices) and 15 representatives (in enterprises with at least 1,000 apprentices).

21 For example, a detailed list of responsibilities for Ireland can be found in the SOLAS Standards Based Apprenticeship Code of Practice (SOLAS, 2017) and the *Apprentice and trainee rights and responsibilities* factsheet published by the Queensland Government in Australia (Department of Education and Training. 2015).

There was a steep decline in the overall number of apprentices in Italy over the period 2008 to 2015 and in Ireland from 2008 to 2013. Overall numbers in France increased steadily between 2009 and 2012, and then declined significantly through to 2015. In Denmark, there was relative stability until 2014, and then a significant decline in overall numbers in 2015 when new entry requirements in Danish and mathematics came into force. The figures for Germany in Table 11 refer to newly concluded apprenticeship contracts and not to overall figures, but here there was a significant decline from 2008 to 2009 and a further gradual decline from 2009 to 2015.[22]

In the non-EU countries, the total number of registered apprenticeships in the USA decreased between 2008 and 2011, before increasing steadily. The total number of apprenticeships in Australia increased significantly between 2008 and 2012, plummeted in 2013 and continued on a downward path.

Age

In the EU Member States, the vast majority of apprentices in Italy in 2015 were in the 20–24 (48.9%) and 25–29 (34.6%) age bands, with a significant number (8.9%) of slightly older people (that is, 30–34–year-olds). Nearly half of apprentices in Ireland are 21 and over. In France, over 80% of apprentices on apprenticeship contracts were 21 and under in 2015, whereas over 70% of apprentices on professionalisation contracts were 22 and over. Given that the German figures refer to apprenticeship starts, it is not surprising that the majority of apprentices are found in the younger cohorts, that is, the 17–20 and 21–25 age groups (56% and 31%, respectively, in 2015).

In the non-EU countries, US data on the characteristics of apprentices are partial because 19 of the 50 states provide only aggregate data. In Australia, a significant proportion of apprenticeship and trainee starts are over 25 years old (40% in 2015).

Gender

In 2015, approximately 40% of apprentices in Italy and just under 50% in Denmark were women. In France, 34% of those on apprenticeship contracts and nearly 50% on professionalisation contracts were women. In Germany, 39% of those starting an apprenticeship in 2015 were women. In Ireland, less than 1% of apprentices are women, mainly because of the types of occupations that have traditionally provided apprenticeships (for example, in the construction and engineering industries).

In the non-EU countries, women make up less than 10% of apprenticeships in the USA, for reasons similar to those in Ireland. In Australia, women make up a slightly larger proportion, more in trade occupations, but around half are in non-trade occupations (12.9% and 53%, respectively, in 2015).[23]

Non-completion

Non-completion is a serious problem in all countries, with the exception of Ireland. In Denmark, the figure in 2015 was 50%; in Italy 38 %; in France 25%, and up to 40% in long-term apprenticeships; in Germany 25% in 2013; and in Ireland a mere 4% in 2014. In Australia, the figure was 53.4% for apprentices in trade occupations starting in 2011, and in the USA around 50%. Again, it should be noted that due to different ways of national reporting of completion and non-completion rates, cross-country comparisons should be made with high caution.

Retention rates

Retention (transition to work) rates are relatively high – 81% in Denmark in 2014, approximately 67% in France and Germany in 2013, but only 34% in Italy in 2012 (ETUC, 2016).

Key challenges

Lack of appeal of apprenticeships

The first significant challenge is social, or rather sociocultural, and refers to the waning demand for apprenticeship places. For many young people, an apprenticeship is not an attractive proposition. This may be because of the restricted types of occupations on offer, as in Ireland, or because of the unappealing working conditions, as in certain occupations in the construction industry or in the hotel and catering industry.

It may also be because they aspire to a university education, as do their parents on their behalf; there is evidence in Australia that the potential pool for apprenticeships has reduced as participation in higher education has increased. Steps have been taken in Denmark to address this issue where the introduction of new EUX-apprenticeships, which confer both IVET qualifications and qualifications from general upper secondary education, should make it possible to improve permeability in the Danish system and enable apprentices to eventually gain access to higher education. The disadvantage with this initiative is that this approach requires more off-the-job training, which may be unattractive for Danish employers.

Supply of apprenticeship places

The second challenge is primarily economic and refers to the supply of apprenticeship places.

Fluctuations in the economy following on from the financial and economic crisis have not surprisingly made employers less certain about what human resources they need in the long to medium term, and this has had knock-on effects for the short term. Moreover, as has been seen in the Irish case, there have been numerous cases of employers going bankrupt and making their apprentices redundant.

22 The overall figure for Germany for 2015 was 1.59 million.

23 Trade occupations include: engineering and science technicians; automotive and engineering trades workers; construction trades workers; electrical trades workers; and other trades workers (such as printing trades and hairdressing). Non-trade occupations are generally to be found in business, administration (general, legal or medical), retail, record-keeping, and ICT/IT information digital media and technology.

In addition, the development of apprenticeship implementation has been hindered by:

- the increase in mergers and acquisitions;
- certain instances of foreign direct investment involving enterprises coming from countries with little or no experience of apprenticeship training and/or little or no willingness to engage in the social dialogue necessary to develop apprenticeship training.

Increased competition, and therefore more pressure to concentrate on short-term productivity gains, may have crowded out the readiness to devote time and resources to apprenticeship training. In this context, also new labour market policies and contractual options to hire workforce might play a role in some countries. There is also an issue which, although not new, is significant; enterprises that specialise in niche activities are often unable to offer the full range of training required to fulfil the demands of the apprenticeship training plan.

Whatever the specific reasons, there is evidence of a gradual reduction in the number of enterprises prepared to take on apprentices, for example, from 24% in 2009 to 20% in 2014 in Germany, a country that has withstood the pressures of the financial economic crisis more successfully than most. Moreover, in countries like Italy with a variety of different forms of work-based learning, employers may be drawn to other cheaper or less bureaucratic forms such as traineeships supported by the Italian Youth Guarantee programme and the open-ended contract with increasing protection (*contratto di lavoro a tempo indeterminato a tutele crescenti*) introduced by the Jobs Act.

In Australia, there is evidence that employers are tending to recruit skilled migrant labour, especially through the employer-sponsored temporary work (skilled) visa programme, and so have less incentive to participate in apprenticeship programmes and provide apprenticeship places.

Matching supply to employment opportunities

Linked to these two challenges is the issue of matching supply to demand in terms of employment, possibly as the result of a less than perfect system of skills anticipation. In some sectors such hotel and catering and cleaning, and also the craft sector in Germany, enterprises have reported significant problems in recruiting apprentices. For example, in September 2016 there was a total of 40,000 vacant places (that is, 8% of the total supply) (BIBB, 2016d).

This mismatch between supply and demand may also be geographical and be linked to the availability of places in VET institutions. In some regions in France, for example, the supply is poorly coordinated and there may be competitive offers in the same geographical area, where demand is itself limited, or offers for apprenticeship in declining occupations.

Matching expectations

There is also the issue of matching expectations between enterprises and apprentices. The most obvious manifestation of this is the high level of non-completion: up to 50% in Denmark; around 50% in the USA; and just over 50% in Australia. Even though there are many potential reasons why young people abandon their apprenticeships, and even if decisions on non-completion are taken most often in the very first stages of an apprenticeship, it is clear that significantly more effort in the pre-apprenticeship phase could mitigate this potential mismatch.

Responding to changing skills needs

Another major challenge is the potential disconnect between the changing skills and qualifications requirements in the workplace, notably in terms of 'soft skills', linguistic competence and IT skills, and the ability of apprenticeship systems to respond.

In some countries, France for example, the official register of jobs and qualifications, which is used as the basis for the curriculum for apprenticeships, is a relatively unwieldy instrument that lags way behind developments in the labour market, making it difficult to adapt apprenticeship training to the needs of the enterprises.

Related to this is the situation in Italy where there are 2,500 occupational profiles for professional apprenticeships, many of which are not clearly defined and some of which, although differently labelled, largely or fully overlap.

In the USA, there is no single approach to defining the list of competences (called 'work processes' in the language of the Office of Apprenticeship) required for each occupation for apprenticeship registration purposes.

The process of modernising apprenticeship programmes in all countries, although exemplary on occasions in the EU Member States such as in Denmark and Germany, is slow and time-consuming in terms of stakeholder involvement. One answer could be to speed up the process, which could potentially reduce the level of inclusiveness of key stakeholders. Another could be to have a more generic framework at the national and/or sectoral level, allowing for greater flexibility at the enterprise level, but this loosening of the system brings its own disadvantages and could potentially lead to a drop in the overall quality of the training. A solution is to be found in France, whereby social partners negotiate agreements to create vocational diplomas or certificates, but the disadvantage of this approach is that apprentices' career pathways are restricted to their own particular sector.

Underrepresented groups

A final challenge relates to underrepresented groups. This may refer to women, most notably in the case of Ireland, where the introduction of new types of apprenticeship outside the traditionally male-dominated occupations is being actively considered. It may also refer, and will increasingly refer, to young migrants or second-generation migrants. Although data are unavailable in some countries, figures from Germany show that only 27% of all young people with a migration background applying for an apprenticeship were successful in 2015; the figure for others without a migration background was 43%.

3 Apprenticeship policy and practice in the manufacturing sector

Apprenticeship as an IVET pathway in manufacturing

An apprenticeship combines on-the-job training in a company and off-the-job training at a vocational school in one overall training experience.

Chapter 2 highlighted the major differences in the country sample for this study concerning the role of apprenticeships as a pathway into IVET. Denmark is the only country studied where apprenticeships constitute not just the dominant, but the only form of IVET. In all other countries, there are also other pathways for IVET. In Germany, the majority of young people leaving secondary education opt for an apprenticeship, while in countries such as Ireland and the USA, only a small fraction of young people choose the apprenticeship route to obtain an initial professional qualification. Table 12 illustrates the relevance of the apprenticeship pathway for IVET in manufacturing.

In Germany, apprenticeship training in general, but particularly in manufacturing, is regarded by all the relevant stakeholders and experts interviewed as a key aspect of the sector's competitiveness as well as its capacity to adjust and innovate. Thus, apprenticeship training in manufacturing is attractive for enterprises. Between 2013 and 2015, the share of enterprise training apprentices was 32.9% in manufacturing and therefore above the average of 20.9% for all sectors (BIBB, 2016b). At the same time, however, the sector's share of enterprises with unfilled apprentice positions was also above average (43.2% against 42%) (BIBB, 2016b). While apprenticeships in the metalworking, automotive and chemical industry are known by – and very attractive for – apprentices due to relatively high remuneration, the newly designed occupation of production technologist is still not known and is judged by some to be too complex in its design.

In France, dual training or *alternance* in the manufacturing sector is attractive for several reasons. The overall duration of dual training courses is in general longer, which implies more solid pedagogical support to master the basic knowledge for the job at hand. Enterprises complete the training of apprentices with on-the-job training. This system makes it possible to prepare future employees to take up jobs by adapting their skills to the evolution of the profession. Dual training is also the best way for young people to enter the labour market. In 2015, between 69% and 75% of apprentices in industrial vocations (depending on the specific curriculum followed) found work within six months of graduating. This compares with an employment rate of young people leaving vocational *lycées* of only 48% on average (Ministry of Education, 2013). Furthermore, the employment rate of apprentices increases to between 80% and 90% when the achieved diploma is of European Qualification Framework (EQF) level 5 or higher (that is, a higher apprenticeship) (Ministry of Education, 2016).

However, there has been a decline in the transition to work rate in France since 2012 due to a depressed labour market. The overall employment rate for apprentices (whatever the nature of diploma prepared) was 62% in 2015. Some industrial sectors have an employment rate higher than average. This is the case for multitechnological production specialist sectors that allow 75% of apprentices to enter the workforce (Ministry of Education, 2016).

Table 12: Relevance of apprenticeship for IVET in manufacturing

Country	Role of dual VET	Key facts
Denmark	Only route	IVET entirely based on apprenticeship
France	Major route	Share of apprentices in manufacturing employment higher than in other sectors
Germany	Major route	71% of all qualified workers in the sector had completed an apprenticeship programme – a higher proportion than in other sectors Share of apprentices in manufacturing workforce higher than in all other sectors
Ireland	Modest	Small number of apprenticeship programmes and limited number of apprentices
Italy	Modest (level I and III)	Level II programmes are not part of the formal IVET system – no national standards Sharp decline in the number of contracts since 2008 (-38.4%)
Australia	Common but not dominant	Approximately 50% of students in manufacturing IVET courses were on apprenticheships Decline since 2012
USA	Marginal	Data available revealed that manufacturing apprentices accounted for only about 7% of all civilian apprentices Lack of standards/significant fragmentation of the apprenticeship system

Source: *Country reports*

Despite these good outcomes, in terms of accessing the labour market in the short term, industrial apprenticeship still suffers from an image problem, especially craftsmanship. The main reason is that vocational education is culturally less valued than general education in France. The attractiveness of these jobs is particularly low among young women who represent less than 10% of apprentices in these sectors. The number of apprentices in industrial enterprises has slightly increased in recent times and amounted to 22% of all apprentices enrolled in 2015. However, the high-tech manufacturing sector represents only a marginal share (which can be estimated at 3% of apprentices), which is greatly below the challenge posed by the digital transformation of production. Although the high-tech sector is attracting more and more apprentices, their numbers remain low with fewer than 14,000 apprentices by 2015 (Ministry of Education, 2016).

This devalued image of apprenticeship is slowly beginning to change, thanks to the development of higher apprenticeships (leading to a higher education diploma) and access to higher qualification through the *alternance* route.[24] This system is no longer restricted to young people who have left school early, but appeals more and more to apprentices who are older and more qualified. Although this trend was detected a decade ago (Abriac et al, 2009), data on the profiles of *alternants* have shown a marked acceleration of the phenomenon in recent years (Ministry of Education, 2016).

In Ireland, apprenticeships in manufacturing are concentrated historically on only a few occupations. Moreover, there is no provision for sector skills councils, which means that there is no formal opportunity for the social partners in manufacturing to meet to discuss the design and implementation of apprenticeship training in the sector, apart from perhaps informal exchanges.

In the USA, the lack of common national standards for occupational profiles and curricula is the main reason why apprenticeship plays only a modest or marginal role in IVET.

In Italy, more than 90% of apprentices are enrolled in Level II apprenticeship programmes, which are not recognised within the formal IVET system and are regulated by national collective labour agreements or other inter-sectoral agreements between the social partners; this has resulted in thousands of different specific occupational profiles, The other two forms of apprenticeship, Level I and III, are recognised within the formal IVET system, namely *Istruzione e Formazione Professionale* (IeFP), IV Anno and *Istruzione e Formazione Tecnica Superiore* (IFTS), leading to EQF level 3 or 4 qualifications and university degrees leading to EQF level 5, 6 or higher, including the higher technical education - *Istruzione Tecnica Superiore* (ITS) - and doctoral degrees. The analysis has shown that the regulation of these other two forms of apprenticeships is extremely diverse (see Box 3) and appears to not be very attractive for enterprises as well as employees looking for IVET training.

When considering the key institutions and players involved in the apprenticeship system in the manufacturing sector, it is important to highlight that the regulatory framework for apprenticeship in Italy does not differentiate between manufacturing and non-manufacturing sectors. There are no specific policies on apprenticeship in manufacturing, and social partners so far have not issued any coordinated systematic demands, apart from references in some collective agreements.

In the USA, estimates suggest that the manufacturing industry accounts for the largest number of apprentices after the construction industry and USMAP.[25] But as there are no nationwide standards, individual employers determine the apprentice occupations that emerge and there is a lack of information on state-regulated apprenticeship programmes.

This experience differs significantly from the structural frameworks and practices in Denmark, France and Germany, as well as, to a lesser degree, in Australia where the role of different players and levels is clearly defined by national regulation and/or conventional practice as described in Chapter 2.

In Australia, apprenticeships have struggled to be seen as an attractive post-secondary education pathway despite the generally good post-training employment and earning outcomes, especially in traditional trades. According to the country report, one factor contributing to this is the decline in trade union membership over this period, as trade unions have been vigorous supporters of apprenticeship training. Various reforms have been initiated over the past 20 years to try and broaden the appeal of apprenticeships, particularly to existing workers.

Occupational profiles of IVET linked to manufacturing and advanced technologies

With no agreed national level definition of the term 'advanced manufacturing', it is not possible to accurately pinpoint any specific IVET profiles and apprenticeship programmes that exclusively cater for the manufacturing sector, though there are programmes that generally tend to focus on employment in the manufacturing industry. This is highlighted in all seven country reports.

24 *Alternance* covers two pathways in France: (1) apprenticeship – initial training that is realised in an apprenticeship training centre (*Centre de Formation d'Apprentis*, CFA) and (2) professionalisation – vocational training that can be realised in several institutions (a college, a training institution, a management or engineering school, or a university). The main difference between the two pathways is the duration of theoretical training. Under the apprenticeship pathways, training in school represents around 50% of the contract (that is, double that in the professionalisation contract). In recent years, higher education institutions such as universities or high schools have opened their degrees to *alternance* training (professionalisation). Bridges exist between lower level diplomas prepared in CFAs and university degrees.

25 As explained in the country report, precise figures on the number of manufacturing apprentices do not exist for two reasons. First, industry details on apprentices in the registered apprenticeship system are available for only the 25 states overseen directly by the Office of Apprenticeship as and federally administered programmes in state administered systems. Second, the available data document only those industries in the registered apprenticeship system. Thus there are an unknown but probably sizeable number of apprenticeships not registered with the Office of Apprenticeship or state apprenticeship agencies.

In Denmark, for example, occupational profiles such as industrial technicians, automatic control technicians and CNC technicians do not necessarily target advanced production specifically, but often provide an entry for jobs in this sector. This applies, for example, to electronics technicians, tool and die makers, process operators, plastics processing operators, technical designers, electricians and various specialisations within metalworkers, and data and communication technicians.

According to the interviewed Danish IVET experts, industrial technicians in particular are prone to ending up in advanced technology sectors. The Industrial Technician Apprenticeship Programme is targeted at the metal industry, where learners are taught to install, repair and operate complicated machinery, involving processes such as drilling, milling, lathing, soldering and integrating CNC and CAD/CAM technology. Depending on the specialisation chosen, the programme may last up to five and a half years, and is situated at EQF level 4 and 5. As industrial technicians are versatile and employed across the board in the manufacturing industry, they serve as a useful proxy or an indicator for developments in the (advanced) manufacturing industry with regard to the role of apprenticeships.

The situation in Germany is relatively similar. Within the manufacturing sector, most of new apprenticeship contracts are concluded in the machine-building and automotive industry; in 2015, there were nearly 150,000, plus the metal making/working and construction sectors (76,000).

When looking at specific apprenticeship programmes/occupational profiles in Germany, it is quite striking that existing programmes are more likely to have been adjusted to new technological requirements than substituted by new programmes. So far, one occupational profile has been established as a new occupation in direct response to new requirements of advanced manufacturing technologies and processes. In 2008, the occupation of production technologist was established following requests from individual enterprises and the engineering employer organisation, with direct reference to the increased role of advanced manufacturing technologies, in particular the use of IT in automation technologies. However, so far only a few new apprenticeship contracts have been concluded by enterprises (for example, 123 in 2015) and other occupations are still much more attractive for enterprises making use of advanced manufacturing technologies. Both enterprises as well as apprenticeship-interested applicants tend to choose established occupations such as mechatronics (26,400 newly concluded apprenticeship contracts in 2015) or electronic technician for automation technology (6,500 new contracts in 2015). However, the traditional apprenticeship occupations of industrial mechanic (46,000) was still the most widespread apprenticeship programme in 2015, though the number of newly concluded VET contracts has decreased by around 10,000 (18%) since 2018, according to the BIBB database DAZUBI (BIBB, undated). According to interviewed national stakeholders, the attractiveness of established occupational profiles results from various factors, including the familiarity of company actors with established profiles and the 'creative leeway' (*Gestaltungsoffenheit*) of occupational profiles that allow for company-specific adjustments according to their specific needs.

In Ireland, there are only a small number of IVET apprenticeship programmes in general, as well as some in manufacturing. These are traditionally to be found in electrical and engineering disciplines, and more specifically for the following occupations:

- aircraft mechanics;
- electrical instrumentation;
- mechanical automation and maintenance fitting;
- metal fabrication;
- sheet metalworking;
- toolmaking.

However, the reforms following the review of apprenticeship training in Ireland in 2013 have led to 'new' apprenticeships such as polymer processing technician (EQF level 6) and manufacturing technician (EQF level 5) which can lead on to a manufacturing engineer apprenticeship (EQF level 6).

In contrast to Denmark, Ireland and Germany, the situation in the other countries studied is much more diverse when it comes to occupational profiles and respective apprenticeship training programmes.

In Italy, the absence of a national framework for qualifications related to Level II apprenticeships results in a situation where occupational profiles related to Level II apprenticeships are defined in collective bargaining by social partners, with the effect that there are thousands of such profiles, many of them overlapping. Although there are initiatives to link these profiles to nationally recognised qualifications (Legislative Decree 13/2013), the work to establish a 'labour atlas' is ongoing.

With regard to occupational profiles considered highly relevant for advanced manufacturing, the Italian country report noted that advanced manufacturing technologies generally require a higher level qualification than that obtained by Level I apprenticeship courses. This could be either longer training durations under Level II programmes (for instance, 36 months leading to the qualification of technician in contrast to only 24 months to become an 'operator') or Level III programmes (see Box 3) that lead to qualifications of EQF level 4 and above.

Similarly, in France, available data indicate that apprentices in industrial occupations tend, on average, to opt for lower level diplomas than in other sectors. Only certain specific apprenticeship schemes touch on advanced manufacturing technologies. These schemes fall under 'multi-technological specialties of production' and encompass high-tech curricula. These specialisations include product design, automation, robotics and industrial computing.

The lower levels of qualification in industrial apprenticeships in France are explained by the predominance of manual occupations and jobs in the automotive, agro-food, mechanical and electrical sectors,

Box 3: Level I and Level III apprenticeships and their relevance for advanced manufacturing in Italy

Level I apprenticeships

For IeFP programmes (EQF level 3), the National Register of Qualifications contains the qualifications defined by the State–Regions Conference in the Agreement of 27 July 2011, updated by the Agreement of 19 January 2012. Of the 22 qualifications, 11 have direct or indirect relevance for manufacturing.

The State–Regions Agreement of 27 July 2011 also defined the occupational profiles of IV Anno (EQF level 4). Nine out of 21 qualifications are directly or indirectly relevant to the manufacturing sector. These are:

- electric technician;
- electronic technician;
- artistic handicraft technician;
- wood manufacturing technician;
- automated industrial machinery technician;
- industrial automation technician;
- apparel technician;
- thermal systems technician;
- food processing technician.

These qualifications together accounted for 3,791 registered persons in 2014/2015 (Isfol, 2016a).

For IFTS (EQF level 4), the 19 occupational profiles defined in the Inter-Ministry Decree of 6 February 2013 are largely services orientated. Just three of them are related to industrial or craft manufacturing:

- industrial design and planning technician;
- product and process industrialisation technician;
- technician for 'Made in Italy' craft products.

Level III apprenticeships

For the pathways in the ITS programme, the Inter-Ministerial Decree of 7 September 2011 defined 29 qualifications at EQF level 5 grouped into six occupational families:

- energy efficiency;
- sustainable mobility;
- new life technologies;
- new technologies for 'Made in Italy'(mechanical systems, fashion, food, housing, business services);
- new innovative technologies for cultural heritage and activities;
- information and communication technologies.

Some of the profiles included in the 'Made in Italy' family may satisfy some of the skill needs of advanced manufacturing.[27]

Source: *Country report for Italy*

among others. Moreover, in certain industrial activities, starting a career at entry level is a non-negotiable condition of mastering basic skills and subsequently evolving towards high-tech jobs. However, industrial enterprises are becoming increasingly demanding in terms of training requirements (Desforges et al, 2014). The share of high-qualification training has therefore increased in recent years, especially for mechanical and electrical jobs, which account for half of all industrial apprentices.

For higher level degrees at EQF 5 or more, training is classified in four disciplines:

- multitechnological specialties of production (high technology);
- processing (agro-food);
- flexible materials;
- mechanical, electrical and electronic.

27 For instance: 'higher technician in the research and development of biotechnology-based products and processes', 'higher technician in automation and mechatronic systems' and higher technician in innovation of mechanical products and processes'. An exhaustive review of the profiles is provided in the online Atlas of Work and Qualifications (*Atlante del Lavoro*: http://atlantelavoro.inapp.org/).

The first category is distinguished by a very high level of qualification. Almost all apprentices in this specialisation prepare for a diploma of EQF level 5 or higher; for example, 44% of them are following a PhD curriculum (Ministry of Education, 2016). This illustrates a developing trend towards higher apprenticeships in certain high-tech fields. However, this trend has to be put into perspective since it concerns only a very limited number of apprentices; about 13,500 apprenticeship contracts in the field of multitechnological specialities of production were registered in 2015, representing only 3.3% of all apprenticeship contracts in the industrial sector (Ministry of Education, 2016).

Apprenticeships in manufacturing in Australia are concentrated at the entry level in traditional trades (automotive, fabrication and mechanical). Manufacturing qualifications have been defined as:

- all qualifications overseen by Manufacturing Skills Australia;
- all qualifications formerly overseen by Auto Skills Australia;
- all qualifications from the printing and graphic arts training package formerly overseen by the Innovation and Business Skills Australia's Industry Skills Council.

In 2014, over 75% of students studying for Certificate III in Light Vehicle Mechanical Technology and over 80% of students studying for Certificate III in Engineering – Fabrication Trade and Certificate III in Engineering – Mechanical Trade were enrolled as part of an apprenticeship or traineeship. In contrast, students in the higher level qualifications such as the Diploma of Laboratory Technology and the Diploma of Engineering – Technical were less likely to be enrolled as an apprentice or trainee, as were students in more specialised courses such as the Certificate III/IV qualifications in Competitive Systems and Practices (NCVER, 2015).

In the USA, the occupational profiles of apprenticeship are developed only through company-specific initiatives. The number of occupational profiles within the federally regulated system with at least one active apprentice is about 620. Additional profiles exist in state-regulated apprenticeships, though the exact number is difficult to determine because not all states list their profiles and because the Office of Apprenticeship does not keep records of all profiles approved at the state level. Each employer or union sponsor often develops and gains approval for their specific apprenticeship programme.

Existing frameworks that specify occupational skill requirements (called work processes by the Office of Apprenticeship) vary widely. For example, one machinist-registered apprenticeship programme presents only one page of work-based learning requirements, listing mostly numbers of hours the apprentice must spend on various machines, hydraulics, pumps and valves. The related instruction page specifies eight courses the machinist apprentice must complete. Another machinist-registered apprenticeship framework, developed by the National Institute for Metalworking Skills (NIMS), is elaborate and detailed, with comprehensive descriptions of the 28 core competencies, performance objectives and performance standards. The detail is such that simply describing the standards and the related instruction takes 35 pages, with clarifying text on each performance object and performance standard, and listings of the NIMS credentials machinists will be able to complete and specifications of which examinations are required. At present, the occupational profiles of registered apprenticeships are housed at the Office of Apprenticeship, but are not readily accessible to enterprises and workforce professionals who may wish to promote apprenticeships. One reason is that, for some enterprises, skill profiles are proprietary and not in the public domain. Furthermore, the skill standards of registered apprenticeships approved at the state level are not transparent and many are not compiled at the federal level.

Role of social partners in apprenticeship policy and practice in manufacturing

As already illustrated, the role of the social partners differs quite significantly, both within the studied EU countries, as well as in Australia and the USA. A closer look at the role and responsibilities of social partners in implementing apprenticeship policy and practice in the manufacturing sector reveals even more differences.

As previously mentioned, the social partners in Denmark play a key role in the whole IVET system and in particular with regard to apprenticeships. Two organisations are particularly prominent for the advanced manufacturing industry. The Confederation of Danish Industry (DI) is an employer organisation covering some 10,000 enterprises especially within manufacturing, but also the trade and service industry. Almost all large enterprises in the manufacturing sector are members. The other is Dansk Metal, which is one of the largest trade unions in Denmark. It organises skilled workers within the metal industry, covering over 90 trades and, as of February 2017, had some 108,000 members, about 9,000 of whom were apprentices. Both organisations are members of the Council for Vocational Training and are represented in the trade committees of relevant apprenticeship programmes at national and local level.

In Germany, the manufacturing sector is characterised by the continuing cooperation and shared responsibilities of the main players involved in the IVET system – the government, employer organisations/chambers of commerce and trade unions as well as IVET schools. For the manufacturing sector, the major social partner organisations, such as the German Metalworkers Union (IG Metall) and the Trade Union for the Mining, Chemical and Energy industries (IG BCE) as well as the corresponding employer organisations – the Federation of German Employer Associations in the Metal and Electrical Engineering Industries (Gesamtmetall) and the Federation of Chemical Employer Associations (BAVC) – and the professional business organisation in the metal and engineering sector, the Association of German Mechanical and Plant Engineers (VDMA), can rely on organisational

strength, resources and capacities that exceed those of other organisations in other sectors. Similarly, manufacturing is a key area of work and expertise of the chambers of commerce and industry that also play a crucial role in the IVET system. The strength of the non-governmental players within the IVET system also has an impact on the joint committees for IVET that exist at national, regional and local level.

In France, the national education authority (Ministry of Education), regions and professional branches are all key players in the industrial sector's apprenticeship system. The national education authority plays a much stronger role in defining and adapting training programmes than in Denmark or Germany, for example. By relying on several parties such as the chambers of commerce or professional branches, the education authorities note the training needs expressed by employers and sectors. Depending on these needs, training programmes are adapted and new courses can be offered. This role is delegated to professional advisory commissions (*Commissions Professionnelles Consultatives*, CPCs), which are managed by the Ministry of Education. The national education system frequently revises training programmes based on the work of these commissions, which play a decisive role in adapting and changing the curricula and their content. CPCs can make proposals on the creation, modification or suppression of technological and vocational training programmes. Currently, there are 14 CPCs covering several different sectors, among which are the metal, chemical, bio-industry and environment industries. Each CPC is composed of 40 members appointed by public authorities and employer or employee federations/ unions. The regions are the competent authority for the implementation of vocational training policy for young people and adults seeking employment or vocational guidance. Each region is in charge of structuring training supply according to business needs. It regulates the opening of apprenticeship training centres as well as the number of available apprenticeship contracts. For their part, sectoral social partners play a role in defining the content of training programmes for specific branches and the respective professional qualification certificates (*certificats de qualification professionnelle*, CQPs). Indeed, the main professional branches have their own apprenticeship training centre; for example, the main metalwork employers' organisation, the Federation of Metalworking Industries and Occupations, has 110 apprenticeship training centres. It employs and trains 40,000 *alternants* each year with 25,000 apprentices and 15,000 students in professionalisation contracts. In several sectors, social partners have concluded collective agreements to develop dual training. In most cases, these agreements provide for quantified hiring targets.

The role of social partners in the national regulation of apprenticeship is more limited in the other countries.

In Italy, the regulatory framework for apprenticeship does not differentiate between manufacturing and non-manufacturing sectors. The central state, regions and autonomous provinces, IVET providers, trade unions and employer associations are all required to play their part in making the system work. However, cooperation is hindered by duplicated effort, fragmentation in policy actions and idiosyncratic failures. As part of the national analysis, the interviewed representative of the National Institute for the Analysis of Public Policy (INAPP) noted some of the difficulties related to the lack of coordination and consensus among the social partners in the definition of a common national framework of qualifications for the Level II apprenticeship or professional apprenticeship (required by Legislative Decree 13/2013). A lack of joint understanding and agreement between the social partners, and conflicts on the basic terms and conditions of employment of apprentices, have resulted in deadlock. The social partners are currently not able to fulfil the role of defining common occupational profiles for Level II apprenticeships delegated to them according to the current legal framework of apprenticeship (Legislative Decree 81/2015). There are no specific policies on apprenticeship in manufacturing, and the social partners, which manage Level II apprenticeships, have not made any systemic demand. The issue is partly addressed in different collective agreements, but there is no specific demand or policy. Large enterprises play an important role in terms of company-specific initiatives.

In Ireland, there is no provision for sector skills councils and so there is no formal opportunity for the social partners in the manufacturing sector to meet to discuss the design and implementation of apprenticeship training in the sector. There may be, however, and indeed there have been, opportunities for an informal exchange of information between IBEC, the employer association, and the Services, Industrial, Professional and Technical Union (SIPTU) on the development of 'new' apprenticeships, particularly in manufacturing engineering and polymer processing technology.

In Australia, historically there has been a very high degree of cooperation and involvement of the main employer association (Ai Group, formerly the Metal Trades Federation) and the principal trade union (the Australian Manufacturing Workers' Union, AMWU) on apprenticeship matters and IVET more generally. This occurs through a variety of consultative mechanisms at the state and federal level. Both groups were represented in the governance structure of Manufacturing Skills Australia, the Industry Skills Council (which formerly had oversight of the manufacturing training package) and Auto Skills Australia, which has responsibility for automotive industry training products. AMWU invests considerable resources in its involvement with the IVET system, for example, by contributing to the most recent review of the manufacturing training package. At the enterprise level, AMWU may include matters relating to apprentices (such as wages and other benefits, and supervision arrangements) in bargaining with companies (Oliver and Karmel, 2011). However, industrial relations legislation restricts the range of such training matters that may be lawfully included in an enterprise bargaining agreement (Stewart, 2013). Group training organisations are another important stakeholder in the manufacturing industry. Under the group training model, the group training organisation assumes the responsibility and risk of employing the apprentice and then hires out them out to companies. The model is particularly useful for smaller

companies which may not be able to provide a rounded apprenticeship, and in regional areas where demand by individual companies may not be able to sustain the employment of a full apprentice.

The USA is a special case characterised by the non-involvement of social partners at the national level and a crucial role at company level. Joint Apprenticeship Committees, in which employers and trade unions are both represented, unionised workers and employers each contribute an amount per hour to finance training centres in the relevant occupation. Employers pay for the wages and the time of the trainer. For a new apprenticeship programme, sponsors submit documentation about how their programme will operate, including lists of competencies that apprentices are expected to learn and the hours of classroom or 'related' instruction. The Office of Apprenticeship or relevant state apprenticeship agency may approve or not approve the plan. One result of this system is that training for a given occupation can follow several different occupational standards. In addition, approvals for registering an apprenticeship programme can vary widely, even for similar proposals, depending on how strict and restrictive are the practices that federal representatives or state agency boards implement. Theoretical aspects of apprenticeships are covered by vocational schools, in particular (for the manufacturing industry) technical colleges. The industrial technician programme, for example, is covered by 16 schools distributed across the country.

Key requirements arising from technological and other changes in manufacturing

Are disruptive technologies putting stress on apprenticeship programmes in manufacturing?

According to a recent French study, the 'industry of the future' requires fundamental knowledge but also technical knowledge that can no longer be taught solely at school before the beginning of an individual's career (Bidet-Mayer and Toubal, 2016). This knowledge should be acquired through vocational experience. The authors argue for a form of 'permanent apprenticeship', which could become the norm in vocational training in the industry of the future.

In this perspective, the typical profile of a worker technician in the industry of the future will be an employee with versatile (ability to intervene on several tasks) and integrated skills (ability to alternate phases of manual work with tasks that require more technical and cognitive skills). The skills needed in the upstream phase of production mostly consist of controlling and programming automated equipment (for example, robot-controlled machines). This requires knowledge of data management and cognitive abilities of abstraction, representation and anticipation. A production operator in the industry of the future will no longer be a 'Taylorian worker' but a 'cognitive worker' (Colletis and Paulré, 2008). In France, a considerable decrease in unskilled employment in the industrial sector in favour of skilled employment has been going on over several years. From 2011 to 2015, the share of skilled workers increased by 4.8 points to 42.3%, while unskilled labour fell by 2.2 points to 6.9% (Eurostat, 2017c).

According to all interviewed stakeholders, VET in general and apprenticeship programmes in particular need to be adjusted continuously in response to technological developments. In Germany, interviewed stakeholders also noted that no specific challenges are emerging concerning new 'disruptive' technologies. However, many of the emerging new technologies are cross-cutting in nature and it is not possible to unambiguously classify them under any one, particular apprenticeship programme. This applies, for example, for robotics, which is a component element in the curriculum of many programmes, such as in the metal trades. However, adjustment needs also depend on the national apprenticeship system and practice. The pressure is likely to be less strong in countries such as Denmark and Germany, where curricula are continuously monitored and updated as needed within the confines of each apprenticeship programme offered and in close cooperation between those involved.

In other countries studied, the VET and apprenticeship system is much more under stress as continuing adjustments are infrequent. For Ireland, the *Future skills requirements of the manufacturing sector to 2020* report noted that scientific advances and technologies such as advanced materials, nanotechnology, biotechnology, phototonics and advanced manufacturing 'are increasingly having a transformative effect on the manufacturing sector now and in the future' and have significant implications for skills (Forfás and Expert Group on Future Skills Needs, 2013). The report highlighted a shortage of workers, in particular at higher qualification levels such as toolmaking and/or machinist skills in engineering and medical devices enterprises, and a shortage or potential shortage of polymer technicians at level 7 in the National Framework of Qualifications (EQF level 6) in medical devices enterprises. The report also raised concern about the supply of mechanical–electronic technicians and trades, but considered that the skills involved could be provided via training covering a combination of mechanical, electrical, electronic and software/IT skills, such as a level 7 (EQF level 6) qualification in mechatronic engineering or an apprenticeship-based qualification in electrical instrumentation.

In France, advanced manufacturing developments related to automation, digitisation and the handling of large data volumes in the production process are regarded as drivers for higher skills requirements rather than for lower level qualifications. According to all interviewed stakeholders involved in VET, new industrial jobs and industries of the future are linked to new skills requirements that are not currently matched by the initial apprenticeship programmes at entry level. These new needs are matched by the various specialisation pathways that are characterised as multi-technological specialties of production related to high-tech skills in, for example, product design, automation, robotics and industrial computing. One-quarter of apprentices in the industrial sector prepare for an EQF level 5–8 diploma

whereas almost half prepare for an EQF level 3 diploma. Apprenticeship in the industrial sector does not lead to a higher qualification for the vast majority of apprentices; only 26% prepare for a higher diploma, whereas the respective share of apprentices in the service sector is around 50% (Ministry of Education, 2016).

These higher level qualifications also exist in Italy, namely the ITS programmes at EQF level 5, which are regarded as highly relevant for advanced manufacturing (see Box 3). Interviewed Italian experts – representing INAPP, the Ministry of Labour and Social Policy (MLPS) and the Association for International and Comparative Studies in Labour and Industrial Relations (ADAPT) – noted that the historical rigidity of the Italian education system has held back the adaptation processes of education and training programmes and contents to the new requirements arising from the transformation of value chains. For this reason, they suggested embracing a different approach that would promote the use of tools such as the National Atlas of Labour and Qualifications (*Atlante Nazionale del Lavoro e delle Qualificazioni*) to describe the occupational outcomes for the recognition of both formal and non-formal learning.

Continuous updating and specialisation rather than creating new occupational profiles

Very few examples of new occupational profiles established in response to new requirements related to advanced manufacturing were identified in the studied countries. Much more prevalent in practice are adjustments of existing occupational profiles, as well as activities to support additional and specialised qualifications.

A relatively comprehensive approach to the rethink of occupational profiles in the context of industries of the future has been taken in France. The Industry of the Future initiative regroups both emerging industrial activities (such as the digital industry and biotechnology) and traditional industries that are transforming and modernising. The general organisation of this plan involves nine overarching fields of innovation. In each field, the plan is driven by a 34 companies selected by the government for their innovative projects.

As highlighted in the French country report, there are at least two new industrial areas and occupations that are regarded as highly relevant. The first is 3D printing ('additive manufacturing'). Jobs are being created in connection with this technology (the use of 3D printers, printing materials, design of printed products and so on). However, training programmes at higher level (for example, engineer or technician) appear to be poorly developed and not matching all of the employers' needs. This new technology, like all disruptive technologies, requires the adaptation of educational content throughout the education system and especially in continuing education (CCI France, 2013).

The second developing sector in France is that of the design, manufacture and maintenance of industrial automation systems. These are generally engineering jobs, for which training is increasingly being carried out in Centre de Formation d'Apprentis, CFAs . Indeed, having a practical in-company component is vital to properly train applicants in this field. Predictive maintenance is one of the most in-demand jobs and consists of predicting the technical malfunctions of equipment and industrial automation by analysing the machines' technical data. This occupation requires both numerical (data analysis) and technical skills. But rather than inventing totally new occupational profiles, the most important way of taking into account new skills and qualification requirements in France is flexible adjustment. In this regard, the Ministry of Education has a leading role in the definition, classification and adjustment of apprenticeship programmes. This work is based on the proposals made by the CPCs in 14 sectors. According to a representative of the Union of Metallurgy and Mining Industries (*Union des Industries et Métiers de La Métallurgie*, UIMM), adjusting the reference system is a cumbersome and lengthy procedure (two to three years to change the content of a curriculum). But as another interviewee mentioned, changing the curriculum every year or so would lead to a general lack of credibility. According to expert interviews carried out in the context of this study, there is in general no disagreement between these different players in terms of introducing a new training programme. However, there is often strong opposition when it comes to closing a training programme that is no longer adapted to the reality of the labour market. Despite the existence of several bodies designed to govern the *alternance* system, the development of a common strategy adapted to regional economic realities is often subject to political or corporatist tensions.

In general, the content of a VET curriculum (within which apprenticeship can be provided) in France is revised once every five years, but this schedule can be more flexible in case of sudden needs. As highlighted by the interviewed representative of UIMM, there are different ways of achieving flexible adjustments of VET curricula. For example, the professional qualification certificates (CQPs) allow the creation or rapid adaptation of training according to the evolution of a profession. The branches have more freedom in the creation and adaptation of a CQP. UIMM has launched several CQPs in the industry of the future, for instance, in the digital sector or robotic and technological systems.[28] However, these certificates are very often closely linked to one specific sector and not easily transferable to another. Most branches try to anticipate change and rely on internal, joint observatories of jobs and skills. For example, the French National Council of Industry (*Conseil national de l'industrie*, CNI) recommends developing a 'shared' anticipation at the intersectoral/interbranch level, emphasising the need to develop a more transversal approach for training instead of a specific need approach. An experiment is being led in the digital industry to develop more transversal training.

In Germany, the existing apprenticeship system is generally flexible enough to adapt the content of

28 Examples include: digital modeller of mechanical products or systems; machining technician on CNC machine tools; integration manager in industrial robotics; automated production systems operator; and automated production systems pilot.

the apprenticeships and occupations to advanced manufacturing.[29] Most enterprises today do not offer training in different or new training occupations, but instead change their apprenticeships through more frequent use of state-of-the-art ICT and personal, social and problem-solving competencies.

As stated in the expert and stakeholder interviews, despite the tendencies of enterprises to adapt training content to their needs, content like knowledge of the production process and the ability to solve problems are still not always as important at the beginning of apprenticeships as they should be. Manufacturing enterprises often do not have enough trained employees with IT knowledge and so an additional qualification for IT in the curriculum would be useful. In general, the availability of supplementary content for curricula is valuable as not all enterprises are at the same stage of development of advanced manufacturing and have the option to decide whether they have a need to teach these qualifications or not.

The introduction of advanced manufacturing technologies and techniques will also have an impact on professional qualifications in the fields of, for example, mechanics, electrical engineering, mechatronics, automation technology and operational technology (see Box 4). In the longer term, there might be a need to adjust the basic profile of future professions and create new profiles such as the occupation technician for system maintenance (*Systeminstandhalter*) (BIBB, 2014b).

It is also important to bear in mind that developments in advanced manufacturing will not take place at the same speed in every company, sector or even region. This needs to be reflected in occupational profiles and curricula that are defined for all enterprises, sectors and regional settings (Zinke et al, 2014).

IVET institutions and company-related players such as employer organisations, chambers of commerce and trade unions have all highlighted that advanced manufacturing is not only about disruptive technologies, but also involves significant further process and organisational changes (as addressed by the Industry 4.0 concept). These changes are leading to more substantive needs for adjustments and modernisation of apprenticeship programmes and occupational profiles.

In France, consultation between various players about training content and adjustments to new skill requirements takes place at the regional level. This was reinforced by the 2014 law on vocational training, employment and social democracy (Law no. 2014-288). The underlying principle is that of quadripartism, that is, consultation between the state, the region and social partners, which gives everyone involved (and particularly professional branches) the opportunity to influence the content and the quality of apprenticeship training. Although the dynamism of these bodies varies from region to region, some are models of virtuous cooperation in adapting and modernising apprenticeship training according to economic and social needs.

Two types of regional good practice are highlighted (National Assembly, 2014). The first involves improving the flow of information on available training and the skills needs expressed by employers (for example, the creation of regional information databases in the Hauts-de-France, Auvergne-Rhône-Alpes and Nouvelle Aquitaine regions). The second consists of the creation of mechanisms to adapt existing training programmes to the needs of the professional branches. One of these mechanisms is the creation of 'campuses of professions and qualifications', which include educational institutions (secondary and higher education, initial or continuing vocational education) and enterprises belonging to an 'excellence' branch at regional or national level. A large number of these campuses belong to the manufacturing sector.

Similarly to France, the social partners in Germany have argued for a modernisation approach that takes into account these new requirements, using agile methodology

Box 4: Adjusting occupational profiles and establishing new profiles in the light of technological change in Germany

BIBB, together with the social partners, regularly updates apprenticeship regulations on behalf of the federal government. Around 100 apprenticeship regulations have been updated since 2008.

Technological change and change in work organisation has influenced the adaptation of the training occupations. For example, in 2014, the occupational profile of the 'automotive body and vehicle construction mechanic' was updated to reflect significant changes in vehicle production technology and processes. In 2011, a new profile for the occupation of 'packaging materials technologist' was established for similar reasons in packaging production. In 2010, the content of the occupational profile of 'paper technologist' was modernised to take account of the growing importance of maintenance and measuring and regulation technology. In the field of industrial electronics, occupational profiles were adjusted in 2003 and new occupational profiles (mechatronics, industrial electrician, electrician for information and system technology, and aircraft electrician) were defined in 2007. Given the strong impact of digitalisation, however, these four occupations in the electrician family are currently subject to another in-depth evaluation (BIBB, 2014b).

Source: *Country report for Germany*

29 This 'creative leeway' (*Gestaltungsoffenheit*) approach is illustrated by the regulation on the examination of apprentices. In the second part of the final examination, the training company has a choice between a standardised national examination task and an operational task reflecting the specific work in the company. Both test professional process competence at a comparable level. Furthermore, the training regulation provides significant time for the provision of a company-specific qualification, giving companies the opportunity to train their apprentices to their needs.

(Gesamtmetall et al, 2017). According to this approach, initial training and qualifications related to advanced manufacturing and Industry 4.0 should take the form of flexible adaptation rather than the development of totally new occupational profiles. However, this initiative also acknowledges the need to integrate:

- new transversal basic skills such as online communication skills, data analysis, data transfer, online searching and online learning skills across all occupations in the metalworking and electronics sector;
- knowledge into all the occupational profiles in the metalworking sector;
- optional additional specific qualifications such as system integration, process integration and additive fabrication/printing in metalworking occupations, and digital networking, programming and IT security in electronic occupations.

The social partners interviewed in the context of this study also stressed the need to strengthen the link between IVET and further training.

This approach was also identified by IVET experts and social partners in Denmark as important. As in Germany, the Danish practice of adjusting apprenticeship programmes involves the introduction of possibilities to specialise as well as optional modules (sometimes shared between different programmes), thus making it possible for apprentices (and enterprises) to put together more individualised curricula that take into account specific requirements. These optional modules and specialisations may also differ in terms of level according to the predilections and the capabilities of the learner. This flexibility means that it is seldom necessary to define new occupations and to develop new programmes, although this has happened.

A further important way to deal with new skills requirements related to advanced manufacturing (seen in Denmark as well as other countries) is to strengthen pathways from IVET into higher level qualification and specialisation programmes.

Higher apprenticeship and pathways into higher education

Most national analysis indicates that advanced manufacturing requires specific skills and competences that are not provided in IVET courses, but that through specialisation, further qualifications can be obtained. However, this should not be confused with 'higher apprenticeships' as the following examples from Denmark, France, Germany and Italy illustrate.

As well as the introduction of additional modules in existing apprenticeship curricula, changes in occupational profiles in Denmark are dealt with through the continuing vocational training system (known as the AMU system), which enables workers to update and extend their knowledge, skills and competences in relation to new technologies and to retain their attractiveness in the labour market. This system also targets adult learners without qualifications, who can enter a special adult apprenticeship scheme which makes it possible for them to obtain IVET qualifications while retaining their job. Prior learning (formal, non-formal or informal) can be accredited to shorten the duration of the programme and enterprises can receive wage compensation from the Employers' Reimbursement Scheme while their employee is in training.

However, higher apprenticeships (that is, higher education programmes being conducted as apprenticeships according to the Cedefop working definition) do not exist in Denmark. A small number of higher education programmes – notably short- and medium-cycle ones offered by the 'universities of applied sciences' or academies of professional higher education and university colleges – are perceived as a direct continuation of IVET programmes. But although they often include work placements, they are basically of an academic nature.

This is similar to the dual study programmes in Germany, which have increased rapidly in recent years and target either higher secondary school leavers or apprentices who have completed an initial apprenticeship programme. Dual academic programmes combine vocational training and degree courses, where the trainee is employed by the company financing the study course and obtains both practical knowledge within the company and an academic degree (bachelor or master, EQF level 6). This field of dual academic programmes is expanding in terms of both the number of programmes and the number of students participating (Hippach-Schneider and Schneider, 2016). In February 2017, there were almost 1,600 dual study courses in Germany, mainly offered by technical colleges in economics and engineering sciences and IT (BIBB, 2014a).

According to German expert and stakeholder interviews, however, the role of dual study courses in the manufacturing sector should not be overestimated. Although no detailed figures on the number of dual students in the manufacturing sector are available, the total number is modest compared with the number of apprentices in the sector. According to Gesamtmetall, there are also indicators that the dual study market in the manufacturing sector will not expand significantly further in the future, as the number of courses and number of dual students have been relatively stable over the past two to three years.

While dual study programmes play an important role in the provision of initial vocational training at tertiary level, they are not considered as higher apprenticeships because they lack certain elements of apprenticeship training (not regulated nationally, social partners not necessarily involved, no uniform system of quality control). However, these considerations apply to advanced further qualifications such as the industry master (*Industriemeister*) or process manager electrical engineering (*Prozessmanager Elektrotechnik*), which are offered to those who have completed, for example, the final examination for the training occupations of industrial electrician, electronics technician for automation technology or mechatronics after one year of relevant occupational practice. For the new occupation of production technologist (*Produktionstechnologe*), which was established in 2008, the further qualification

certificate 'process manager production technology' (*Prozessmanager Produktionstechnologie*) was created.

According to stakeholder interviews in many of the countries involved in this study, there is a need to develop new forms and opportunities in continuing education and on-the-job training. Learning should not stop after an apprenticeship. Lifelong learning is already considered in apprenticeship regulations, but there is a need to enforce this element more strongly.

In Italy, the interviewed representative of the trade union confederation CGIL suggested the need to introduce Level III apprenticeship programmes into a broader planning of local value chains, involving employer associations, policymakers and trade unions. In a productive system made of many SMEs, often embedded in geographical clusters or industrial districts, this is considered the correct way to boost higher apprenticeships. This would transform Level III from a niche tool to a useful instrument for all companies that want to innovate and invest in a highly qualified workforce.

There have also been initiatives to better link apprenticeship and continuing learning in Italy. One provision of Legislative Decree 13/2013 (implementing Law 92/2012, also known as *Legge Fornero*) is to establish a national system that promotes the integration of continuing VET into the formal education system that might also have an impact on apprenticeship. According to VET experts (Isfol, 2016b), this would bring a fundamental transformation of existing practice because, until now, continuing training is offered in a way that is fragmented, occasional and often self-referential. According to CGIL, strengthening of the further qualification system is also necessary in terms of worker requalification and retraining in the context of rapid technological change in the manufacturing sector. Apprenticeship, if combined with continuing VET, could be a smart instrument to address those issues.

Stakeholders and experts in France have also stressed that, in the light of the accelerated change in the industrial sector, a comprehensive rethink and change of initial and further VET and qualification and a better linkage between both is required. While traditional industries and trades are under increasing pressure due to automation, new industrial jobs are appearing. Both trends require increased efforts of further qualification and adjustment. The field of continuing vocational training is much more open and competitive. In this field, branches have progressively developed their own qualifications (CQPs) that can be recorded or not in the national repertoire of qualifications. The regulation here is, of necessity, the product of concertation between several players.

France also exemplifies a unique approach to the development of higher apprenticeships, with the extension of apprenticeship to higher education in the 1990s. This trend has caused a major change in the profile of apprentices in recent years, especially in the manufacturing sector. This extension of the apprenticeship system to higher education is also an opportunity to bring university and workplace closer together, thus making the students' professional integration easier. The 'universitarisation' of apprenticeship has also caused the specialised industrial sector to start using the *alternance* system, especially for the higher qualification levels (bachelor and master).

Higher apprenticeships are valued by French enterprises because they provide for opportunities to train employees with cross-functional technical skills and to develop a collaborative working culture between employees from different professional backgrounds. This type of crossed curriculum requires the creation of new courses and innovative pedagogical formats. This is the case of *Ecole supérieure des métiers* (CESI Alternance), a network of several private training centres that turn to and adopt *alternance* courses through apprenticeship schemes. These centres train engineers using the 'active learning by project' method, which consists of complementing technical and fundamental skills (hard skills) with transversal skills (soft skills such as ability to work in a team, ability to innovate, entrepreneurial spirit, management and management in project mode).

UIMM for its part is experimenting with this new pedagogy of learning by project and plans to extend it to all of its training centres. The idea is to have apprentices from different industrial specialties working on the same project (for example, the manufacture and marketing of a specific product). The aim is to train an engineer or technician to be capable of understanding all the phases of the production of a product from its conception to its commercialisation, through manufacturing and marketing.

Similar debates on increasing skills requirements and the need to improve the link between formal and further/ongoing VET are reported for Australia and the USA. Actual initiatives are, however, concentrated on specific sectors/occupations and more fragmented than in the five EU Member States covered in this study.

Stakeholders interviewed in the Australian manufacturing industry noted a growing demand for new and developing paraprofessional[30] and technician roles. The transition from standardised production lines to more specialist runs, as well as the adoption of more robotics and automation, is creating demand for technicians capable of programming machinery rather than just operating it. These roles are developing from production workers instead of traditional trades' workers. In the area of 3D printing and additive manufacturing, actual occupation profiles are yet to become clear. The range of skills that will be required spans the use of materials in design, 3D design and potentially equipment maintenance, combined with a more general skillset involving enterprise skills.

In Australia, apprenticeships – especially in the trades – have focused on Certificate III level qualifications. There are some traineeships (which operate like apprenticeships,

30 Paraprofessional roles are non-technical roles that typically require a diploma-level qualification.

in that they involve a contract of training tied to a contract of employment) associated with diploma-level qualifications, but these have had low uptake and have generally suffered from the problems associated with the traineeship system more broadly, such as poor quality of off-the-job training and treating traineeships as a de facto wage subsidy scheme (Schofield, 2000; Cully and Curtain, 2001; McDowell et al, 2011, p. 36).

Australia's complex industrial relations system has also inhibited the development of higher level apprenticeships. Apprenticeship arrangements are written into modern awards, and the process for changing them is protracted and requires considerable consultation. A report on the development of higher apprenticeships in Victoria found that the strongest demand for degree qualification and higher level technical skills is in the engineering sector, in areas such as mechatronics (Guthrie and Dowling, 2012, p. 3).

Over the past 20 years, there have been various initiatives to launch 'cadetships' aimed at higher level qualifications in the engineering and related sectors. For example, the Smart Skills Initiative in Queensland involved a new cadetship programme and targeted paraprofessional roles in the electrical generation industry and other sectors. It did not involve a formal apprenticeship or traineeship (Misko, 2008). In 2004, the Australian Industry Group developed the 'technology cadetship', which involved a formal combined contract of training and employment like an apprenticeship or traineeship lasting one or two years. The cadetship involved multiple exit points into different job classifications built around the Certificate III/IV in manufacturing technology. It still existed in 2017 as a separate pathway alongside the traineeship in manufacturing technology.

Given the lack of national occupational frameworks in the USA, it is difficult to detect adjustments of company-based programmes made in response to technical change and the increasing skill requirements of manufacturing occupations. What has been noted is that the closer interaction of electrical and mechanical trades has spurred a large demand for mechatronics apprenticeships. Continuing moves towards digitisation are increasing skill requirements in many professions and expanding the demand for IT workers.

To stimulate apprenticeships in occupations outside construction, the US Department of Labor awarded USD 175 million (€148 million) over five years to 46 grantees as part of the American Apprenticeship Initiative. Some 65% of the 46 grants under this initiative target manufacturing, including production occupations such as assembly and fabrication, metal and plastic working, and plant and system operation. The grantees are diverse, ranging from state agencies to community colleges to local non-profit organisations. One example focused on manufacturing is the grant to the Illinois Advanced Apprenticeship Consortium. Maintenance apprenticeships on advanced equipment are among the primary occupations sponsored by the consortium, which is working with its members to establish apprenticeship programmes that emphasise advanced manufacturing occupations.

One broad initiative stimulated by grants from the US Department of Labor is the creation of the Industrial Manufacturing Technician Apprenticeship (AFL-CIO Working for America Institute, undated). Several organisations, including trade unions, collaborated to create this new apprenticeship framework. This 18 month or 3,000 hour apprenticeship trains workers of all ages to:

- set up, operate, monitor and control production equipment;
- improve manufacturing processes and schedules to meet customer requirements;
- understand manufacturing as a business system that integrates multiple disciplines, processes and stakeholders;
- manage time and materials efficiently and safely.

The apprenticeship framework reflects the increasing skill demands in manufacturing, although the number of apprenticeship sponsors and apprenticeships that will be generated under it is unclear.

Box 5 describes one of the few examples of a higher dual VET programme in the USA.

Box 5: Higher dual IVET programmes in the USA

The Registered Apprenticeship Community College consortium (US Department of Labor, Employment and Training Administration, Office of Apprenticeship, 2017) is an initiative to link apprenticeships with two-year college programmes. The goals include providing apprentices with accelerated pathways to earn an associate's or bachelor's degree by counting some work-related training as for-credit courses.

Virtually no US apprenticeship programmes are affiliated with four-year, BA programmes. One notable exception is the bachelor's degree programme involving a partnership between Old Dominion University in Newport, Virginia, and Newport News Shipbuilding. For example, students at Old Dominion University can now do a four- to eight-year stint as apprentices at a nearby shipyard while simultaneously earning a bachelor's degree in mechanical or electrical engineering. The apprentices spend a day or two per week in the classroom and the rest of their working week on-the-job at Newport News Shipbuilding. Old Dominion's apprenticeship scheme began in 2013. The programme is quite expensive to enterprises, working out to at least USD 225,000 (€190,460) paid for wages, tuition, fees, textbooks and a benefits package during each apprenticeship's course (Fain, 2015).

Source: *Country report for the USA*

Challenges related to vocational schools and in-company training personnel

Most of the country reports point to certain challenges as regards IVET schools such as:

- those related to the competences and further qualification needs of IVET personnel;
- software infrastructure;
- the use of new technologies;
- financing schools' modernisation.

A recent study stressed that there is a lack of teachers in vocational schools in Germany, especially in natural science and technical subjects that are highly relevant to advanced manufacturing, as well as adequate instruction methods in the training of teachers (Ernst, 2016). A further weakness relates to the financing of IVET schools. Financial resources in economically better off federal states are much better than in regions characterised by fiscal strains and restricted budgets. The resources between sectors, as well as regions, also differ significantly in terms of school modernisation as well as innovation (for example, the creation of competence centres in specific industry sectors or professional fields).

A further weakness of apprenticeship training in the manufacturing sector relates to the limited number of instructors and tutors in enterprises. The number of instructors fell between 2009 and 2015 by about 4% in total, according to the Federal Statistics Office (Destatis). Furthermore, full-time instructors as defined in the Ordinance on Trainer Aptitude (*Ausbilder-Eignungsverordnung*, AEVO) are a minority in German enterprises today (BIBB, 2012). In addition, in the context of Industry 4.0, there is a need for 'instructors 4.0'. But according to interviewed stakeholders and experts, the instructors do not always have the required knowledge of advanced manufacturing and lack pedagogical skills.

An OECD report that identified some limitations in apprenticeship training in France (Brandt, 2015) in particular highlighted a lack of training and certification for apprenticeship tutors in enterprises. Furthermore, the report notes a lack of professional staff coming from industry into apprenticeship centres, in particular teachers with professional experience and 'cutting-edge' technological knowledge. The evolution of teachers' skills is also at stake. Indeed, their initial training is often not in line with the new technologies used by enterprises, as highlighted in surveys among chief executive officers (Bidet-Mayer and Toubal, 2016).

Despite the existence of both national and regional bodies, coordination between the different players (CNEFOP and its regional equivalents) and cooperation on the subject of apprenticeship training programmes is often difficult. This is notably the case for negotiations about the content of training curricula and the establishment of training programmes. Competition between apprenticeship training centres and vocational high schools (*lycées professionnels*) is a direct consequence of this lack of cooperation. Competition arises because both systems are trying to attract a maximum number of students in order to maintain the activities of their establishments and thus the employment of their teachers. Sometimes the same specialised training is offered in both systems (professional high school, apprenticeship in an apprenticeship training centre) in the same territory even when demand is insufficient or in decline. In many regions, concerted action on the vocational education map is rife with tension, especially when it comes to rationalising the training offer. Another area under development is that of cooperation between teachers in apprenticeship training centres and company mentors. This form of cooperation is underdeveloped in France compared with other countries (Brandt, 2015).

The analysis of the situation in Denmark also highlighted weaknesses in IVET schools. Being able to offer adequate training for the needs of the advanced manufacturing industry requires sophisticated hardware and software, which needs to be updated or replaced frequently due to the rapid pace of technological development. Since vocational schools in Denmark are self-owning institutions financed according to their activity level, smaller schools can find it difficult to keep abreast of developments and to offer suitable equipment for technology-intensive programmes due to economic constraints. This will, over time, lead to a specialisation among vocational schools, where certain programmes are concentrated in specific schools, which either because of size or prioritisation are able to provide state-of-the-art facilities. This is also valid for human resources, where teachers and instructors need to update their skills and knowledge to adequately support learning processes of apprentices from enterprises using advanced technologies.

To accelerate this development, the Ministry of Education recently announced the creation of a number of knowledge centres in selected fields, two of which (robotics and automation and process technology), are of direct relevance to the advanced manufacturing sector. These knowledge centres are to be placed in selected vocational schools and will receive earmarked funding for the purchase of sophisticated hardware and software and the development of the competence of their teachers.

Advanced manufacturing: Mapping reform processes and adjustments

Three dimensions of adjustments

The review of reform processes and adjustments of national apprenticeship systems identified a broad number of initiatives that vary according to initiators (for example, national or regional governments, social partners, VET institutions and single enterprises) as well as in relation to their scope (for example, targeting the whole VET system including apprenticeship or not) as well as concrete objectives. It should also be noted that reform initiatives and adjustments vary as regards the linkage to advanced manufacturing. While in some countries reforms or adjustments are directly related to technological changes, adjustments in other countries are driven by other motivations and objectives, such as the attractiveness of apprenticeship or improvements of the system or specific aspects.

In order to map different initiatives, three dimensions of reform processes seem particularly relevant.

- **Systemic dimension**: Integration of different occupational fields, horizontal links, hybrid qualifications as well as educational paths into the apprenticeship system from initial to higher apprenticeship and beyond.
- **Regulatory dimension**: Occupational profiles and programmes containing requirements on basic and general skills provision across different occupations, occupation-specific skills as well as company-specific skills acquisition and offers for further qualifications.
- **Individual dimension of apprenticeship**: Learning processes, learning methods and learning environments.

Approaches and initiatives to adjust existing practices to better cope with the challenges in the context of advanced manufacturing have been developed in regard to all three dimensions. However, reform initiatives at systemic/structural level mainly target the whole apprenticeship system in the studied EU countries and Australia, and general VET system and school-to-work transitions in the USA (Table 13).

Systematic dimension

- Key aspects addressed by reforms are linked to general national challenges, such as the attractiveness of apprenticeship among your people (all EU countries).
- High dropout rates in Italy and an increasing number of apprenticeship places by enterprises (Denmark, Germany, Italy).

The focus of these reforms is the whole system of apprenticeship, with only a few initiatives targeting manufacturing in particular.

In relation to the role of social partners in adjusting apprenticeship, there are large differences across the countries covered in this study, ranging from no significant role at all to a strong systemic and institutional embeddedness. Social partners play an important role in Denmark and Germany, whereas in France and Italy their role is mainly concentrated on supportive functions in terms of implementing IVET programmes and lobbying for policy change and reforms. Only in Denmark and Germany was a continuous adjustment of apprenticeship programmes and curricula reported as being an important feature of the apprenticeship system with social partners being key players in making requests and co-managing apprenticeship programmes. In all other countries, social partners do not seem to have similar direct influence on the conception and implementation of apprenticeship programmes.

Regulatory dimension

There are also quite stark differences in relation to reform processes and initiatives aimed at modernising existing occupational profiles and qualifications, and developing new profiles in response to advanced manufacturing requirements. Only Germany has adopted a process of adjusting IVET practices directly in response to technological change and new skills needs stemming from the digitalisation of the whole economy, including advanced manufacturing. In Denmark, France and Germany, advanced manufacturing within the apprenticeship system is addressed as an important aspect in the context of national programmes for the development of IVET knowledge centres (Denmark, Germany), IVET school modernisation (Germany) and professional campuses (France) that acknowledge the crucial role of new technologies and respective skills requirements. In all the other countries, however, such initiatives are limited to regional and local innovation and good practices, and often to individual enterprises (Australia and the USA).

Individual dimension

There are certain similarities between the EU countries and differences with the two non-European countries when it comes to the individual dimension of adjustments and reform initiatives.

In all the EU countries, IVET school modernisation and quality improvement initiatives and programmes can be found in response to adjustment needs resulting from technological change and new requirements. While in Denmark and France such programmes have been a main element of broader national reforms, Germany recently launched an IVET school modernisation programme that directly refers to:

- new requirements and needs in the context of new technologies;
- the need to modernise school infrastructures and education provision.

Perhaps more limited but similarly linked to Industry 4.0 policy initiatives, Italy has also seen the modernisation of VET courses. Modernisation initiatives of learning methods, practices and environments have also been the aim of the establishment of competence or knowledge VET centres on specific technologies, such as those for automation and robotics established in Denmark, Germany or France ('campuses of professions and qualifications'). Apart from state-of-the-art learning techniques and equipment, these centres are often also related to regional technology clusters and business.

Other aspects

A further focus of public reform initiatives has been to enhance the attractiveness of the apprenticeship pathway for young people. Such initiatives have been launched in Ireland (new apprenticeships at EQF level 6) and Australia. In Australia, as well as in the USA, however, such initiatives (which also include the development of new occupational programmes) are largely business-driven and take place outside the formal public regulatory framework of apprenticeship.

Finally, the link between VET/apprenticeship reform processes and industrial policy initiatives overall is relatively weak. Only three countries have launched

Table 13: Mapping reform initiatives

Country	Systemic dimension	Regulator dimension	Individual dimension
Denmark	Targeting general weaknesses: high dropout rates and increasing attractiveness of apprenticeship Manufacturing social partners' initiatives to increase attractiveness of apprenticeship in manufacturing and technical professions Building bridges into technology professions for young people with fewer opportunities	Continuing process of adjustments of occupational profiles and curricula at national level Company-specific initiatives to improve or complement national apprenticeship programmes (for example, giving apprentices a higher skills profile with additional theoretical courses, *erhvervsrettet påbygning*) and 'talent tracks' (*talentspor*) for gifted apprentices within the framework of the national apprenticeship programmes	National programme of modernisation and quality improvement of IVET schools (linked to 2014–2015 reform) Creation of knowledge centres Introduction of a 'placement guarantee' in 2016 for selected programmes (such as for industrial technicians) guaranteeing an apprenticeship contract if learners choose to sign up for training programmes from a selected list (for example, an industrial technician programme) IVET schools running transnational mobility programmes with local enterprises
France	Numerous initiatives and acts that aim to increase the number of apprenticeship places provided by enterprises Social partners initiatives to increase the attractiveness of apprenticeship in manufacturing and technical professions	Mainly company-specific initiatives to adjust or develop new training programmes and courses that reflect requirements arising from advanced manufacturing	'Campuses of professions and qualifications' created in the context of the educational reform of 2013 Training and apprenticeship projects at regional level, launched in the context of industrial cluster policies and the Industry of the Future national plan of 2013
Germany	Improving transitions from the VET into the tertiary education system Social partners initiatives in manufacturing to increase attractiveness of apprenticeship in manufacturing and technical professions	Continuing process of adjustments of occupational profiles and curricula at national level Intensified anticipation and monitoring of skills needs in the Vocational Training 4.0 initiative and new approaches of social partners (for example the Agile Method of adjusting occupational curricula and further qualification/specialisation needs)	VET school modernisation and investment programmes such as the government's 1,000 IVET Schools 4.0 launched in 2016 Establishment of sector-related VET competence centres (*Überbetriebliche Berufsbildungsstätten*, ÜBS) Company-specific training centres that offer training for other local enterprises
Ireland	Reform of the apprenticeship system including new administrative and governance structure at national and regional level	Comprehensive revision of existing apprenticeship and development of new qualifications in manufacturing occupations	Two new apprenticeships with direct links to advanced manufacturing – both located at EQF level 6 and thus 'higher' apprenticeships
Italy	Different forms of apprenticeship training (Levels I, II, III) have been addressed by various national reform acts during the past 15 years – latest act in 2015 aims to increase the attractiveness of Level I and Level III apprenticeships	Initiatives to integrate Level II apprenticeship programmes with NQF/EQF have been unsuccessful. Company-specific initiatives of modernising and adjusting curricula and training contents	Regional IVET schools have initiated a number of new programmes and innovative courses, reflecting the government's recent Industria 4.0 policy initiative
Australia	Systemic reforms mainly aimed at reforming public financial support, skills anticipation and addressing skills shortages, as well a support for specific groups of learners/apprentices	Modernisation of sectoral skills councils and occupational training packages Development of an 'advanced manufacturing qualification that reflects emerging technologies' is included in the four-year work plan of the Manufacturing and Engineering Industry Reference Committee	Pilots on higher apprenticeship exist but are currently not covered by the general, legal and industrial relations regulatory framework of apprenticeship in Australia

Table 13: Continued

Country	Systemic dimension	Regulator dimension	Individual dimension
USA	Reforms at national level aim at a better and more systemic integration of apprenticeship in the overall workforce system (one encourages closer linkages between Workforce Investment Boards and apprenticeship), but collaborations between apprenticeships and schools, including vocational programmes, remain limited	Initiatives to adjust occupational profiles and develop qualification programmes targeting skills for advanced manufacturing are limited to individual federal states US Department of Labor has contracted outside experts to create competency-based national frameworks for apprenticeship	Mostly local initiatives driven by local partnerships/community colleges More innovative programmes carried out in federal states in close cooperation with multinational enterprises focusing on 'higher apprenticeship', not registered with US Department of Labor

Source: *Country reports*

broader national economic policy initiatives that target modernisation processes in relation to advanced manufacturing:

- Germany (Industrie 4.0);
- France (Industries of the Future);
- Italy (Industria 4.0).

Though all have a strong link to the challenges and tasks of adjusting and improving initial and further VET, so far only Germany has also launched at national level a corresponding programme of modernising VET policy (Vocational Training 4.0). In France, as well as Italy, such VET initiatives so far exist only at the regional and local level.

Country-specific developments

Reforms and government-led initiatives

In Denmark, major structural reforms were undertaken in 2001 and again in 2014–2015 that targeted the whole system of apprenticeship and not advanced manufacturing in particular. The latest reform of 2014–2015 mainly addressed problems related to drop-out rates (with the introduction of the 'completion guarantee')[31] and the attractiveness of IVET (see Box 6). Further focal points of the reform include better access to higher education for people with IVET qualifications and the increased well-being of learners attending vocational schools.

The 2014–2015 reform in Denmark also involved the:

- allocation of funds for IVET school modernisation, namely supporting the purchase of new equipment (hardware and software) to enable them to keep abreast of developments in technology;
- the setting up of eight knowledge centres in vocational schools as of 2017 to act as vanguards for the continued development of teaching and teaching methods in accordance with technological progress within these fields.

Two of the themes for these knowledge centres are of direct relevance to the advanced manufacturing industry:

- automation and robotics (two knowledge centres);
- process technology (two knowledge centres).

The centres will be run by a partnership of vocational schools and involve external partners. For example, higher education institutions and partnerships were formed during the first half of 2017 after a tendering procedure, and the centres were expected to commence operations

Box 6: Increasing the attractiveness of apprenticeship in professions with labour shortages in Denmark

The Danish social partners in tripartite negotiations with the government also agreed to make annual lists of apprenticeship programmes leading to those occupations most likely to be affected by a shortage of manpower. For these programmes, the employers have promised to find apprenticeship contracts for at least 9 out of 10 learners. In return, employers who sign apprenticeship contracts are entitled to a bonus up to DKK 5,000 (approximately € 670 as of 17 May 2018) per year, as long as the programme is on the list (which is revised annually). The list for 2017 contains a total of 33 programmes, 7 of which can be associated with advanced manufacturing (one of these is the industrial technician programme, the others as automation technician, electrician, toolmaker, various types of metal workers, industrial and process operators).

Source: *Country report for Denmark*

31 The completion guarantee guarantees that learners can finalise their chosen programme even when they do not find an enterprise to sign an apprenticeship contract with. It also gives them the option of continuing the programme in a 'placement centre' in case they cannot find an in-company placement.

in the second half of 2017, according to the Ministry of Education and Training.

In Germany, the latest larger and more systemic reform of the apprenticeship system was carried out in 2005, aimed in particular at increasing the permeability of the IVET system by simplifying the transition of people having completed an initial apprenticeship into tertiary education or the acknowledgement of prior qualifications. At present, there are a number of reform processes and government-led initiatives to adjust the apprenticeship system with the aim of making it fit for the future and to cater for the needs of advanced manufacturing and Industrie 4.0.

These reform initiatives address different dimensions of adjustments, ranging from individual learning processes, methods and learning environments to modernising occupational profiles in relation to entry requirements, specific skills provisions, as well as the provision of transversal skills across different occupations. Further areas of adjustments and modernisation relate to the development of further qualification modules focusing on the provision of specific skills and competences for advanced manufacturing technologies and processes. In addition, there are adjustments and initiatives that have a more systematic and structural dimension, such as:

- the integration of different occupational fields;
- strengthening horizontal links between occupational profiles;
- the development of hybrid qualifications;
- strengthening and fostering educational pathways from the apprenticeship system into higher apprenticeship and tertiary education.

In terms of modernising occupational profiles, as well as improvements in vocational education practices and available infrastructures and competences, the Vocational Training 4.0 initiative of BMBF (in cooperation with BIBB) has been the most comprehensive approach to address various challenges and requirements in relation to new technologies and changing skills needs (see Box 7).

The comprehensive process of modernising the apprenticeship system underway in Ireland entails the revision of existing qualifications as well as the preparation of a number of new apprenticeship qualifications. An example for the adjustment of an existing occupation is the 'Mechanical Automation and Maintenance Fitting' apprenticeship, with a new curriculum issued in April 2017 following a review in 2015–2016. The Apprenticeship Council approved the development of 25 totally newly designed apprenticeships, two of which relate to the manufacturing sector –'polymer processing engineer' and 'manufacturing engineer. They are placed at EQF level 6 and thus should be considered examples of 'higher apprenticeship'.

Although apprenticeship has not always been the target of IVET reform policies in Italy, it has been repeatedly modified over the past 15 years. This process led to the current threefold system of apprenticeship, where Level I and Level III apprenticeships are integrated with the IVET offer, while Level II largely focuses on transition into employment and is highly fragmented due to a lack of

Box 7: Vocational Training 4.0 in Germany

The Vocational Training 4.0 initiative launched by BMBF in 2016 includes (BIBB, 2016a, 2016c):

- company-based in-depth research by BIBB on new occupational profiles in the automotive industry (Operative Maintenance 4.0);
- the screening of selected occupations and further qualification practices to adjust needs and requirements arising from advanced manufacturing technologies and digitalisation.

A further focus of the Vocational Training 4.0 initiative is to improve the digital competences of apprentices and teaching/training personnel by:

- supporting digital forms of education and the use of digital media, Web 2.0 and mobile technologies in education and training;
- training educational staff and strengthening the resources of VET schools.

This modernisation programme is supported by 1,000 vocational schools (Schools 4.0) 4.0, an investment programme by the Federal Ministry for Economic Affairs and Energy (BMWi) (BMWi, 2016). A further component of this initiative is the establishment of industry-specific competence centres (ÜBS) that focus on advanced technologies and processes related to Industry 4.0, such as automation and robotics, new materials and biotechnology.

According to the interview with a BMBF representative, the Vocational Training 4.0 initiative indicates a stronger role by the federal government (in cooperation with BIBB) in activities to adjust and modern the apprenticeship system. In the past, the government has focused more on the (legal) implementation of changes agreed between the key stakeholders in the IVET system (enterprises, employer and union organisations) or providing research intelligence (BIBB). The Vocational Training 4.0 initiative implies a more proactive role. Its results should, however, feed into the tripartite social dialogue on the further development of the IVET system.

Source: *Country report for Germany*

national regulation of qualification and skills provision at company level. According to the current legal regulation of apprenticeship, only Levels I and III belong to the national IVET systems, whereby education is organised by the state and professional training is constitutionally devolved to the regions. Level II apprenticeships are mainly assigned to social partners' collective agreements, with the regions in charge of training outside enterprises.

In France, one important outcome of the IVET reform in 2013 was the establishment of campuses of professions and qualifications. These seek to improve IVET and to bring it more in line with company-specific needs. There are currently 77 campuses designed to allow enterprises to play their role in the development of training programmes adapted to their professional needs. The campuses cooperate with academic institutions at secondary and higher education level, initial or continuing education, apprenticeship training centres, other IVET providers and single enterprises. The campuses focus on new and advanced technologies, and industries such as creative and digital imaging, innovative materials, biotechnology, aeronautics, smart building and mechatronics. According to French stakeholder interviews for this study, the campuses and their close cooperation with enterprises have contributed to improvements in the quality of apprenticeship programmes, as well as a better visibility of apprenticeship in the respective sectors. Other positive effects highlighted in the interviews were the joint development of training course contents, cooperation in teaching and the provision of state-of the art specialised technical equipment.

A further impetus for fostering adjustments in IVET and apprenticeship practices in France has been the national industrial policy on advanced manufacturing, the Industry of the Future plan launched in 2013. This plan has seen the inauguration of several industrial clusters such as the Jules Verne Manufacturing Valley in the Pays-de-la-Loire region. Developed by public and local authorities, this cluster gathers industries together to form a 'competitiveness cluster' (*pôles de compétitivité*), which includes a training centre, among other elements. Apprenticeship therefore has a major role to play. Within this cluster, the Institut de recherche technologique Jules Verne carried out an experiment that involved apprentices from different backgrounds and qualification levels (engineers, graduate students, baccalaureate professionals and holders of a CQP) working on the same project (intra-level training) with the aim of building bridges between different diplomas and find common modules (Agera, 2015). The institute is dedicated to the industry of the future and provides training in several specialised fields, such as robotics, augmented reality, simulation and modelling, composite processes and metal processing. This manufacturing academy has multiple objectives including:

- implementing new training methods by using technological facilities;
- providing a large selection of apprenticeship training ranging from professional bachelor to engineering degree;
- offering in-house training, continuing VET;
- motivating young people to work in the manufacturing industries.

In Australia and the USA, reform trends are quite similar but differ significantly in terms of the role of national-level regulation and reform processes. In Australia, and more so in the USA, apprenticeship as such has not been a particular focus of systemic reform or regulatory changes in response to emerging needs arising from technological change.

In Australia, the 2010 and 2015 reforms of the apprenticeship system mainly aimed at changes in the general framework such as:

- public subsidies;
- encouraging the integration of indigenous and disabled apprentices;
- improving foresight and anticipation of skills' requirements in areas with skills shortages.

These changes had no specific reference to manufacturing or advanced manufacturing. Thus, the interviewed stakeholders in Australia agreed that apprenticeships and IVET could be more strongly incorporated into industrial policy initiatives targeting advanced manufacturing. The initial National Innovation and Science Agenda, released by the federal government in 2015, did not mention IVET or apprenticeships (Australian Government, 2015).

In addition, major industrial policy initiatives make no direct reference to apprenticeship but contain only general commitments to improve IVET activities in the light of new emerging skills needs. One example highlighted by stakeholders is the support programme for the defence industry which includes the establishment of a Maritime Technical College in South Australia (Australian Government Department of Defence, 2017). The college will identify, train or retrain Australian workers for the local defence shipbuilding programme. In general, the defence sector is an important contributor to training in the manufacturing industry, with considerable access to equipment and resources. The recently announced initiative in the food manufacturing sector, which includes the establishment of a Food Agility Cooperative Research Centre, also includes a link to workforce qualification. To help the Australian food industry grow its competitive advantage through digital transformation, the programme will examine how digital technologies can support the workforce to be more productive, overcoming skill shortages. In addition, the Growth Fund launched by the Australian government in 2016,[32] in response to the announcement by Ford and Toyota that they were going to cease local automotive production, includes a commitment to allocate financial funds to a skills and training initiative to help workers gain recognition for their skills and to train for new jobs.

As well as national industrial policy initiatives, the Australia country report highlighted initiatives adopted at the level of regional government with a focus on manufacturing. Examples are the Manufacturing Industry

32 See https://www.business.gov.au/assistance/advanced-manufacturing-growth-fund for more information.

Action Plan of the New South Wales government which outlines a strategy for manufacturing in the state over the decade to 2021 (Manufacturing Industry Taskforce, 2012). The plan also includes a recommendation for a wide-ranging review of education and training after year 10, with the focus on raising the status of IVET among school leavers (Manufacturing Industry Taskforce, 2012).

The Queensland government in December 2016 released the Queensland Advanced Manufacturing 10-year Roadmap and Action. The plan includes a commitment to develop an advanced manufacturing skills, training and workforce development strategy plan (Queensland Department of State Development, 2016, pp. 25–26).

At present, there are no specific advanced manufacturing qualifications in any of the manufacturing-related training packages.[33] However, the component file of the MSA07 Manufacturing Training Package does have a suite of qualifications in manufacturing technology (Certificate III to Advanced Diploma level). The Diploma of Engineering – Advanced Trade from the MEM05 Metal and Engineering Training Package takes into account the increasing importance of advanced manufacturing to the associated advanced engineering tradesperson job role (Manufacturing Skills Australia, 2015, p. 640). Furthermore, the Manufacturing and Engineering Industry Reference Committee in its four-year work plan 2016–2017 to 2019–2020 includes the development of 'an advanced manufacturing qualification that reflects emerging technologies' (Manufacturing Skills Australia, 2016, p. 60).

Although most of the vocational programmes at US high schools and community colleges have industry advisory committees, the linkages between schools and employers are uneven. The US country report highlighted the Apprenticeship 2000 programme in North Carolina, where a set of enterprises and schools worked closely to develop high-quality, manufacturing apprenticeships (Adenberger, 2013). Other states – notably Georgia, Maine and Wisconsin – have given high priority to youth apprenticeships. In Wisconsin, state agencies, collaborating with industry and labour groups, developed around 23 skill standards in fields ranging from the printing and automotive industries to biotechnology and finance. The standards require high-level competencies achieved at the workplace, as well as related academic instruction, often delivered through technical colleges (Lerman, 2014). This programme could serve as a good practice example of innovations with regard to advanced manufacturing as it focuses on occupational areas such as engineering, machining, maintenance, installation and repair, and bioscience. In Colorado, the state's governor is attempting to replicate aspects of the Swiss apprenticeship system by establishing youth apprenticeships in late high school that involve a combination of work-based learning, paid work and production, and classroom learning.

The US country report also points to initiatives involving workforce qualification at sector and local level that emerged in the 1990s and have been recently revitalised by the 2014 reauthorisation of the Workforce Investment Act. Under this Act, state plans must describe how employers will be engaged, including through industry sector partnerships that involve multiple employers in an industry cluster, unions and local organisations and government agencies. Local workforce boards (typically standalone units created to administer federal grants and overseen by boards made up of business, labour representatives and government) allocate funding to develop, convene or implement sector partnerships. Some plans include local or state sector partnerships of companies in selected manufacturing sectors, but few plans emphasise manufacturing apprenticeships.

Against the overall weak impetus coming from national level regulation, innovations and initiatives to adjust youth apprenticeship frameworks and programmes are mainly found at the individual state level or initiated by single enterprises.

Social partners' initiatives

To tackle the lack of attractiveness of apprenticeship among young people, Danish social partners have created a number of initiatives. Four of these relate specifically to the manufacturing industry.

- DI ran an initiative in 2014–2016 that aimed to increase the number of apprenticeships in industry by campaigning among enterprises to offer more apprenticeship places.
- Dansk Metal and DI, together with three other relevant trade unions, launched in 2013 the ongoing campaign Hands-on, which targets young people and seeks to influence their career choices in the direction of apprenticeships in the industry.
- Five technical colleges offering the industrial technician programme have, together with a number of enterprises engaged in technically advanced production, launched the campaign Industritekniker.nu, which seeks to attract more young people to the programme.
- The recruitment problems encountered in the industry led DI and the Danish Industry Foundation to initiate a project called New Tracks towards Technology, which ran from 2013 to 2015. The project targeted young people with fewer opportunities and developed programmes that sought to motivate and prepare them for apprenticeships in industry. The project's approach has been adopted by education institutions and recommendations for the government to deal with education and training for young people with fewer opportunities.

Social partners in Germany have also initiated joint activities to adjust the apprenticeship system to new requirements resulting from technological change and advanced technologies. The social partners in the

33 Training packages define the components of nationally recognised qualifications (competency standards or units of competency, qualification frameworks and assessment guidelines). They are elaborated by approximately 70 national Industry Reference Committees and endorsed by the Australian Industry and Skills Committee. Training packages define the individual units of competency that relate to each particular industry sector and the rules for bundling them into nationally recognised VET qualifications.

metalworking and electronics industries have developed their own approach for the adjustment of relevant occupational profiles, apprenticeship programmes and further qualification or specialisation modules in line with the Agile Method (Gesamtmetall et al, 2017). In 2014, the social partners in the chemical industry sector presented a joint approach for the additional funding of vocational schools and their closer cooperation with enterprises in consideration of the rapid pace of technological change (IG BCE and BAVC, 2014).

In Italy, with its regional fragmentation and sectoral patterns that largely depend on the willingness of social partners to implement joint approaches, most initiatives and innovative approaches to modernise and adjust apprenticeship programmes, curricula and the contents of occupational profiles, come from individual enterprises and local IVET providers.

In France, there are initiatives by the social partners to improve the image of apprenticeship training and IVET in the manufacturing sector. For example, UIMM periodically organises 'in-company classes', which involve inviting a class of high school students and their teachers for a weekly immersion in an industrial working environment. The goal is to allow them to discover the broad spectrum of professions that exist within the industry and encourage them to embark on an apprenticeship programme after having completed college.

Company-specific initiatives

At the level of individual enterprises, there are examples of large manufacturing enterprises in Denmark that have used the possibilities of the national PIU Programme or the EU Erasmus+ programme[34] to send apprentices abroad on both short - and long-term placements to complement the training that is available at home. This is often done in collaboration with the vocational school. For example, Mercantec, a large vocational school in mid-Jutland, runs an annual scheme co-financed by the Erasmus+ programme where local enterprises (including Grundfos, a worldwide advanced manufacturing enterprise) send apprentices on placements in enterprises in Germany and the UK.

Individual companies in Germany are important drivers of adjustment processes of apprenticeships in the manufacturing sector. Larger enterprises in particular have developed their own activities to improve apprenticeship training and adjust in-company training to new requirements. A prominent case, as highlighted by interviewed stakeholders, is that of ABB (with its training centres in Berlin and Heidelberg), where apprenticeship training is implemented in a cooperative way involving apprentices from 18 partner enterprises and technical universities (*Fachhochschulen*) in different occupational fields including mechatronics, electronics, industrial mechanics, manufacturing mechanics, tool mechanics and commercial apprentices.

A further prominent example is the education department of Siemens AG, which is one of the leading enterprises in modernising and adjusting training contents, as well as methods to adapt them to the needs arising from digitalisation and advanced manufacturing technologies such as robotics and additive manufacturing (Kunz, 2015; BMWi, 2017). The training and education provided by Siemens Professional Education covers 30 different apprenticeship occupations and 40 different dual academic programmes in fields such as electronics, IT, mechanical engineering, mechatronics and business administration. The educational programmes offered are organised in a modular way.

Also, in sectors not linked to robotics or automation, larger enterprises have initiated comprehensive projects to better address issues related to new technologies and advanced manufacturing processes within their apprenticeship programmes and higher VET. Here, the aircraft builder Airbus is a prominent example, launching in 2016 a large digitalisation project in its IVET activities. Airbus Germany, together with other aerospace enterprises, is also actively involved in regional industrial policy cluster initiatives (for example, in Hamburg and Bremen).

In Italy, company-specific examples with a strong link to advanced manufacturing, highlighted by interviewed stakeholders, include the Level III apprenticeship programme at the Enel Group (also involving smaller enterprises), which was launched in 2014. The programme opened the way to the use of apprenticeship as a dual-learning instrument in second-grade secondary schools, which was afterwards included by the Jobs Act in the Level I framework. A university–industry initiative relevant to the modernisation of the higher apprenticeship training offer and with direct links to advanced manufacturing is the Bosch Industry 4.0 Talent Programme – in cooperation with the Politecnico of Milan – which was launched at the beginning of 2017 for graduates in engineering, physics or mathematics (Level III apprenticeship).

An example of good practice in terms of social partners' cooperation in the context of Level II apprenticeships is that at the IMA Group in the Emilia-Romagna region where the company and the trade unions' representatives jointly define the individual training plans of the apprentices. With regard to Level I apprenticeships, the employer organisation Confindustria has highlighted the practice at the Loccioni Group (IT solutions for the manufacturing sector) as a positive example of creating local networks involving second-grade secondary schools and higher education institutions.

Apart from single enterprises, there are VET schools and institutions in Italy at regional level that have developed programmes and training courses addressing new requirements related to advanced manufacturing. Most examples (ITS Lombardia Meccatronica, ITS Maker, Motorvehicles University of Emilia-Romagna and University Master courses in additive manufacturing and

34 As part of Erasmus+, a new activity called ErasmusPRO has been introduced with a view to increasing long-duration mobility for VET learners from three months to up to one year, mainly in work placements abroad. The purpose is to strengthen the professional and soft skills of learners and broaden their horizons, while enhancing their employability.

Manufacturing 4.0 at the Politecnico of Turin) are located in the industrialised regions in northern Italy and address apprenticeship programmes at Level III.

Some of these programmes refer directly to the Industria 4.0 national plan launched in 2016 by the Ministry of Economic Development (MISE) and the Ministry of Education, Universities and Research (MIUR). This underlined the need for a tighter integration between industrial development and the training of innovative skills and competences, though no strong links were made with regard to apprenticeship training.

In France, a number of company-specific initiatives[35] are aimed at improving training and apprenticeship programmes in response to new requirements related to advanced manufacturing, for example, in the field of machine engineering and automatisation. Such initiatives have resulted in updated skills repositories and the respective adjustments of training courses or new forms of training provisions in 'learning factories'. These are company-based training and learning centres that teach not only apprentices but offer also continuing education courses (Enke et al, 2017). Another more frequent example concerns cooperation between one or more enterprises and a training centre to develop tailor-made training (for example, in the aerospace manufacturing sector), cooperating closely with apprenticeship training centres.

Related to higher apprenticeship programmes, the country report for Australia identified two business-led pilot initiatives as relevant for advanced manufacturing, both sponsored by the national government and implemented by sectoral professional organisations such as the Australian Industry Group (Ai Group), public IVET institutions and universities, as well as private enterprises (PricewaterhouseCoopers, Siemens). One of the initiatives launched in 2016 was a Higher Level Applied Technology apprenticeship project, involving 20 participants undertaking a Diploma and Associate Degree in Applied Technologies. The pilot is being developed by Siemens Ltd and Swinburne University of Technology, and participants will be provided with guaranteed pathways to a relevant bachelor degree by 2020 (Ai Group, 2016). The programme includes a rotation of participants through companies involved in Siemens' supply chains, including a placement at Siemens in Germany. The programme does not actually fall within the formal definition of an apprenticeship in Australia as the obtained VET degree (Diploma of Applied Technologies) does not come from an existing training package.[36] In practice, however, participants in the pilot scheme have been employed on the condition that they undertake the off-the-job training associated with the qualification.

In the USA, there are examples of manufacturers at individual company level that have developed their own apprentice-style training programmes. Among the more innovative programmes are the Kentucky Federation for Advanced Manufacturing Education (KY FAME) programme at Toyota, at ThyssenKrupp in Illinois and the fast-growing Youth Apprenticeship Programme in South Carolina. KY FAME created coalitions of manufacturing companies developing new occupational frameworks, while ThyssenKrupp established a mechatronics apprenticeship that includes earning dual high school and community college credits.

However, not all of these programmes are registered with the US Department of Labor. In the context of the KY FAME programme, students are involved on a combination of education and training programmes to earn certification as an advanced manufacturing technician. They attend classes at a local community college 2 days per week and work 24 hours per week for a local employer – all while being paid a competitive wage. After five semesters, students will earn an Associate in Applied Science degree in the industrial maintenance technology–advanced manufacturing technician track, two years of work experience and Advanced Manufacturing Technician certification.

35 One example of cooperation between companies and CFAs to adapt or create specific diplomas is the creation of the BTS diploma in plastic composite adapted to aeronautics by a joint initiative of the Airbus Group and the CFA for the Loire-Atlantique region. Another example is the creation of an automatic welding specialty in a general industrial welding diploma. This specialty has been created on the initiative of a group of companies in the aeronautical industry.

36 The qualification has also not been approved by Victoria or any other state or territory jurisdictions as an appropriate qualification/vocation for an apprenticeship. This means that the contract of training is not legally linked to the contract of training and the apprentices cannot be engaged as apprentices (or trainees) under the industrial relations framework.

4 Strengths and weaknesses, success factors and barriers

On the basis of emerging challenges and new training requirements in the manufacturing and advanced manufacturing sector, this chapter summarises the strengths and weaknesses of the apprenticeship systems and practices on a country-by-country basis, and examines the success factors and barriers to further development from a comparative perspective.

Strengths and weaknesses of apprenticeship systems and practices

In terms of key strengths, the following aspects are regarded as very important:

- the strong overall commitment of key stakeholders in most countries;
- the quality of training to support the future careers of apprentices;
- the established pattern of funding on the basis of public–private partnership, with the exception of the USA;
- the capacity to adjust and react to new commercial and labour market developments, albeit with different levels of urgency.

In this context, a particular strength of apprenticeships compared with other IVET pathways is undoubtedly the relatively close link between IVET and the labour market, leading to some form of equilibrium between the supply and demand of skills and jobs. When only few jobs are available, enterprises will only take on a small number of apprentices. This balance also avoids training people for qualifications and careers in areas where employment prospects are not promising.

An important strength – particularly in countries such as Denmark and Germany – is the strong commitment of all the actors involved and the stable consensus between social partners, as well as across political parties, regarding the added value of the apprenticeship system. Further strengths relate to the capacity of national systems to modernise and adjust to new skills requirements, albeit to a different extent, depending on country specifics and institutional frameworks. The possibility of transition from initial to 'higher' apprenticeship or tertiary education has also been highlighted as a key strength in some national apprenticeship systems.

In terms of key weaknesses, two stand out across most countries:

- the general lack of attractiveness of apprenticeship training, even if it provides non-negligible benefits in terms of pay, and as a basis for entry into the labour market and an initial career perspective;
- the high level of non-completion (albeit to a less extent in Germany and France), with the exception of Ireland.

Against this background, the focus of recent public reform initiatives in many countries has been to improve the quality and image of apprenticeships, particularly among young people.

Other weaknesses relate to:

- the limited number of apprenticeship programmes in general, and of relevance for advanced manufacturing in particular;
- the mismatch between the supply and demand of apprenticeship places, particularly in the high-tech sector;
- the limited cooperation between stakeholders at various levels;
- the fragmentation of responsibilities in some countries.

Interestingly, lack of a higher apprenticeship offer was not identified by the consulted national stakeholders as a weakness of current apprenticeship practices in those countries that do not have provision for higher apprenticeships. What was highlighted, however, as a weakness in two countries is the lack of 'permeability' (that is, the inability to reduce barriers) between apprenticeships and tertiary education (Germany) and high schools and colleges (the USA). Given the increased need for continuing learning, skills development and acquisition of knowledge in the context of rapid technological change, this weakness was highlighted by various stakeholders in these countries as a serious challenge.

Table 14 summarises the key strengths and weaknesses of the national apprenticeship systems emerging from the country reports.

Table 14: Strengths and weaknesses of national apprenticeship systems and practices

Country	Key strengths	Key weaknesses
Denmark	○ Entire IVET system is based on the apprenticeship model – the combination of school-based and work-based training ○ High quality of training provision ○ Programmes fit employers' needs and are adjusted regularly based on new needs ○ High retention rates	○ Slow and time-consuming process for the modernisation of existing apprenticeship programmes or for the establishment of new ones ○ Insufficient provision of apprenticeship places by companies in the high-tech sector ○ Lack of attractiveness of apprenticeships in manufacturing compared with academic pathways ○ High non-completion rates
France	○ Proactive role of social partners in the provision of apprenticeship training and the modernisation of curricula ○ Adaptability of the apprenticeship system by opening it towards higher apprenticeships ○ High retention rates	○ Lack of attractiveness of apprenticeship in manufacturing for young people ○ Adjusting the reference system is a cumbersome and lengthy procedure ○ Limited provision of apprenticeship programmes and places, particularly in the high-tech manufacturing sector ○ Qualifications of staff at VET schools
Germany	○ Programmes fit employers' needs and are adjusted regularly based on new needs ○ Shared responsibility of actors involved at company and national level ○ Flexible character of apprenticeship programmes, with an openness to respond to skills requirements arising from technological change ○ High quality of training provision ○ High retention rates	○ Slow and time-consuming process for the modernisation of existing apprenticeship programmes or the establishment of new ones ○ Lack of attractiveness in manufacturing compared with academic pathways for young people ○ Weak links to continuing training and qualification and transition routes into tertiary education (though the formal possibility exists, very few apprentices make such transitions)
Ireland	○ Relatively high level of stakeholder involvement (particularly from employers) ○ Capacity to modernise and adjust occupational profiles, albeit slowly ○ Relatively low non-completion rates	○ Limited number of occupational programmes and respective apprenticeship programmes in general, manufacturing in particular ○ Very low participation of young women in apprenticeships
Italy	○ Apprenticeships as an effective training pathway and potentially promoting labour market integration (in manufacturing)	○ Lack of national recognised certification of occupational profiles (Level II apprenticeships) ○ Weak and fragmented multilevel governance ○ Lack of attractiveness of apprenticeship as an IVET pathway ○ High non-completion rates
Australia	○ Strong commitment of employers and enterprises, as well as trade unions and training providers, to the development and adjustment of apprenticeship programmes ○ Strong network of public and private providers	○ Slow pace of revising nationally recognised qualifications ○ Fragmentation of responsibilities for apprenticeship ○ High non-completion rates
USA	○ Innovative examples illustrate the added value of apprenticeship training, in particular for advanced manufacturing ○ Cost efficiency of apprenticeship compared with other IVET paths ○ Attractiveness of apprenticeship for manufacturing companies and young people	○ Absence of a national or even regional framework for apprenticeship training ○ Lack of overall generalised political and business commitment to apprenticeship training ○ Lack of transparency of occupational profiles of registered apprenticeships approved at the state level ○ Weak link between apprenticeship programmes and high schools and colleges ○ High non-completion rates

Source: *Country reports*

Success factors and potential barriers to future development

This study has identified a number of success factors and barriers to the further development and adjustment of apprenticeship systems in the manufacturing and advanced manufacturing sector. These relate to:

- the role of apprenticeships within IVET;
- attractiveness;
- cooperation and responsibilities;
- financing;
- adjusting and modernising apprenticeship programmes and higher apprenticeships.

There are significant differences between the countries studied in relation to the importance of apprenticeship within the IVET system. In Denmark and Germany, apprenticeship is the only or the dominant form of IVET; Denmark and Germany are striking examples for consensus and close cooperation in IVET. Between key stakeholders (governments, social partners, enterprises and IVET providers), this was also highlighted as a success factor, albeit to a lesser extent for France and Ireland.

In countries such as Denmark, Germany and Ireland, the roles and responsibilities of the stakeholders involved are clear and the apprenticeship system incorporates well-functioning horizontal and vertical articulation of interests in decision-making and practices, and communication and coordination at different levels. In most countries, there is also an established pattern of funding for apprenticeship training on the basis of public–private partnerships.

In some countries, there has been significant and continued commitment from political leaders and governments to the adjustment and modernisation of apprenticeship programmes and adequate financial resources have been devoted to this effect. The ability to respond to take regional and/or enterprise-level specifics into account has been highlighted as a success factor in Denmark, Germany, Italy and the USA.

The German system has traditionally made provision for higher apprenticeships – *Meister* qualifications – and there are the beginnings of higher apprenticeship pathways resulting in nationally recognised qualifications in France, Germany, Ireland and Italy.

Important barriers have been identified with regard to regulatory frameworks. Apprenticeship is in competition with other IVET pathways in France, Italy, Australia and the USA, and there is an absence or weakness of national frameworks and acknowledged standards in Italy (for Level II apprenticeships) and the USA. Barriers that relate to governance were reported as a hindering factor in particular for Italy, Australia and the USA where roles and responsibilities within the multilevel system of governance are unclear.

With regard to processes and quality of framework conditions, as well as attractiveness of apprenticeships, employers in Italy consider that involvement in apprenticeship is too burdensome from an administrative point of view and too expensive. Employers in certain sectors (notably high tech and IT) have been slow to embrace apprenticeship programmes in Germany, Ireland, Italy and the USA. Moreover, employers in some countries – namely France, Italy and the USA – have little faith in the quality of the off-the-job training, whether because of its content, the experience of the training staff or the availability of appropriate training equipment.

The absence of nationally recognised qualifications, as in Italy and the USA, may put young people off embarking on an apprenticeship. Young people are generally attracted to more prestigious academic pathways, which may lead to more interesting career opportunities and a higher lifetime income.

In terms of adjusting and modernising apprenticeship programmes, there is an absence of enabling factors such as political leadership, social partner involvement and resources (for example, in Italy and the USA). Moreover, there is often some confusion as to the definition and distinctiveness of existing apprenticeship programmes, which may inhibit cross-sectoral skills acquisition – particularly in France, Germany, Ireland, Italy and the USA.

The boundaries between apprenticeships and the higher education system inhibit the development of higher apprenticeships in all the countries covered by this study. Moreover, there is an absence of adequate offer of further qualifications at higher levels in Denmark, Germany, Australia and the USA. Where higher level programmes exist, they often have little or no link with the apprenticeship system (for example, academic courses with limited or no on-the-job learning components) and have limited appeal for companies.

Table 15 summarises the key results of this study in terms of success factors and potential barriers to the future development of the apprenticeship system and practices.

Table 15: Success factors and potential barriers to further development from a comparative perspective

	Success factors	Barriers to further development
Legal regulation – role of apprenticeship within IVET	• Apprenticeship plays the major and most valued role within IVET (DE, DK) • Strong commitment of governments, social partners, enterprises and IVET providers towards apprenticeships (DE, DK, FR, IE)	• Apprenticeships competing with other VET pathways (FR, IT, AU, US) • Absence of national frameworks and acknowledged standards (IT as to Level II apprenticeships, US) • Limitations in terms of occupational programmes (IE, AU)

Table 15: Continued

	Success factors	Barriers to further development
Attractiveness of apprenticeship for companies	○ Companies via employer organisations are directly involved in shaping apprenticeship programmes (DE, DK, FR, IE) ○ Flexibility of adjusting programmes according to own needs (DE, DK, FR, IE, US)	○ Limited attractiveness and quality of apprenticeship programmes and greater emphasis on theoretical training by IVET providers (FR, IT) ○ Bureaucratic burden, costs (IT) ○ Lack of provision of apprenticeships in certain sectors and company size groups (for example, high tech and IT) (DK, DE, IE, IT, AU, US) ○ Poor quality of the off-the-job-training in relation to contents, trainers and/or equipment (IT, US)
Attractiveness of apprenticeship for young people	○ Apprenticeship offers good career opportunities in the labour market (DE, DK, FR, IE, US) ○ Apprenticeship contracts and financial conditions are attractive (DE, DK, FR, IE, US) ○ Possibilities of further career paths by further qualification/specialisation and/or academic paths (DE, DK, FR, IE)	○ Absence of national recognised qualifications (IT as to Level II, US) ○ Perceived attractiveness: general upper secondary education and higher education is perceived as more alluring (DE, DK, FR, IE, IT, AU, US)
Cooperation and responsibilities	○ Clear responsibilities (including personnel, financial, others) of all players involved (DE, DK, IE) ○ Well-functioning cooperation, communication and task coordination of actors at different levels (DE, DK, IE)	○ Unclear division of responsibilities between national and regional/local level (IT, AU, US) or difficult cooperation of relevant stakeholders on apprenticeship training programmes (FR)
Financing of apprenticeship	○ Shared financing of public and private players involved (enterprises, social partners and IVET institutions) (DE, DK, FR, IE, IT, AU)	○ Absence of national financial framework (US)
Adjusting and modernising apprenticeship programmes	○ Strong commitment of political leaders/ government (DE, DK, IE) ○ Joint social partner initiatives are actively supported by governments (DE, DK) ○ Provision of sufficient financial resources (DE, DK, FR, IE) ○ Expertise as well as resources at regional/ local level, as well as within involved organisations/institutions (DE, DK, IE) ○ Flexibility of existing apprenticeship programmes to integrate company-specific or regional particularities (DE, DK, FR, IT, US)	○ Absence of enabling factors such as political leadership, social partners involvement, resources and expertise (IT, US) ○ Too narrowly designed occupational programmes and respective apprenticeship programmes that hinder cross-sectoral skills acquisition (DE, FR, IE, IT, AU, US)
Higher apprenticeship	○ Traditions of nationally certified further training schemes building on completed apprenticeship training, for example, certified specialist/supervisor (*Meister*, Technician) (DE, IT) ○ Higher apprenticeship pathways developed within the apprenticeship system resulting in nationally recognised qualifications (FR, IT and though not classified as such, IE)	○ Too strict boundaries between apprenticeship and higher education system (DE, DK, FR, IE, IT, AU, US) ○ Higher apprenticeship courses with no link to the traditional apprenticeship system (for example, academic courses with on-the-job learning components) and limited involvement of social partner organisations (DE, IE, IT)

Note: *AU, Australia; DE, Germany; DK, Denmark; FR, France; IE, Ireland; IT, Italy; US, United States of America.*
Source: *Country reports*

5 Conclusions

The main objective of this study was to provide a comparative overview of apprenticeship systems in a select number of countries and to review developments in these systems in response to labour market shifts, changes in employment, as well as new requirements for skills and qualifications emerging from technological and structural changes in the manufacturing and advanced manufacturing sector.

This report, as well as the underlying more in-depth analysis of the seven country reports, has shown that there are similar challenges, as well as national approaches, to industrial policies relating to advanced manufacturing technologies. At the same time, there are significant differences in terms of national apprenticeship systems and their ability to make necessary adjustments, and to contribute to a successful adaptation of manufacturing to advanced technologies, processes and business models.

All countries reviewed in this report have legal frameworks for apprenticeship in place. Yet, significant differences exist in aspects such as:

- the role of apprenticeship within the overall initial vocational and education training (IVET) system (including initial as well as higher VET);
- attractiveness for learners and companies;
- the involvement and shared responsibilities of the key private and public actors involved.

Against this, the main added value of this study is the contribution to a better understanding of different apprenticeship systems in the manufacturing sector, including country-specific challenges and reform processes. The study also identified a number of strengths and weaknesses, as well as success factors and barriers, as regards adjusting apprenticeship systems and practices to the needs of manufacturing and in particular advanced manufacturing.

Modernisation of apprenticeship systems and practices

In some countries and under certain conditions, governments – often with the full participation of social partners – have already introduced important measures to overcome the identified barriers to the further development and modernisation of apprenticeship systems. Most countries studied (Denmark, France, Germanyand Italy) have recently amended or developed legislation leading to the establishment of national qualification frameworks.

Some countries (for example, Ireland) have undertaken reviews of apprenticeship training leading to major changes in their apprenticeship systems. Ireland has completely restructured its administrative structures for implementing apprenticeship policy, with the establishment of the Apprenticeship Council. This has led to a process of reviewing occupational profiles, learning outcomes and curricula in existing apprenticeships, and developing new apprenticeship programmes.

In countries with strong traditions of dual apprenticeship training such as Denmark and Germany, national governments and social partners have recently developed new or revised strategies for apprenticeship training. In Germany, the federal and regional governments and the social partners have agreed a joint strategy, the Alliance for Initial and Further Training 2015–2018, which contains a series of measures to better prepare young people for their occupations and the world of work. In Denmark, the Improving Vocational Education and Training reform proposed that:

- a minimum entry requirement in Danish and mathematics would be introduced;
- apprentices would have an opportunity to specialise more gradually by reducing the 12 vocational access routes to 4 broader areas (care, health and pedagogy; office, trade and business services; food, agriculture and experiences; and technology, construction and transportation) and by introducing a foundation course;
- apprentices would have the opportunity to obtain a general upper secondary qualification offering access to higher education.

Adjusting apprenticeships in the context of advanced manufacturing

Although the term ‘advanced manufacturing’ is not always the main term of reference used in public policies and industrial policy initiatives, it is gaining ground in all seven countries in this study as an important reference term.

References to advanced manufacturing technologies are made in key government policies such as Industrie 4.0 in Germany, Industrie du Futur in France and Industria 4.0 in Italy, and also in national industry initiatives such as the Manufacturing Extension Programme in Australia and the National Strategic Computing Initiative in the USA. Despite targeting the whole economy and not just manufacturing, the Danish government’s plan for continued economic growth makes a strong reference to advanced technologies such as robotics and automation as a means to enhance productivity and retain jobs in the country.

At the same time, there are significant differences between the countries in relation to links between industrial policy initiatives addressing advanced manufacturing and VET systems, including apprenticeships.

Denmark and Germany have developed the most comprehensive approaches to modernising and adjusting apprenticeship training in response to technological change, particularly in manufacturing and advanced

manufacturing. The analysis of Denmark has shown that, according to interviewed stakeholders and major global actors in the field that are exposed to international competition, apprenticeships in the advanced manufacturing industry are regarded as highly relevant, adequate and fully capable of delivering training of a quality that meets the needs of enterprises. Germany's dual IVET system is regarded as a key component of the success of the national manufacturing sector and as a crucial prerequisite for its high productivity, in the global context. Given the high share of manufacturing employment in the total workforce in Germany, it is also not surprising that manufacturing and technological modernisation is high on the agenda of VET research and social dialogue, as well as public policy. This is not only illustrated by the number of initiatives in Germany that target advanced manufacturing in terms of skills development and IVET requirements, for example, the VET 4.0 initiative of the federal government, as well as a range of initiatives by trade unions and employer organisations at sector level. In both Denmark and Germany, the adaptation of apprenticeships to advanced manufacturing has not primarily been addressed by introducing new occupational profiles but rather by adapting the existing ones.

In all the other countries studied, the link between advanced manufacturing and IVET is weaker, and other needs are higher on the national reform agendas. The French and Italian industrial policy initiatives respond to the decreasing employment in manufacturing in general and the aim of fostering – in line with EU policy – an 'industrial renaissance'. Within this agenda, the links to IVET are rather weak (particularly in Italy) or, as in France, focus more on the promotion of jobs in industry as future-oriented and as attractive career paths (compared with high-tech academic pathways). In Australia and the USA, there is so far no link between industrial policy initiatives and IVET. And in Ireland, the development of apprenticeship programmes related to advanced manufacturing has to be seen in the context of the overall IVET policy reform that seeks to expand apprenticeships across all sectors.

In some countries, it is mostly company and local level initiatives that illustrate the added value of apprenticeships. This is particularly the case in Italy, Australia and the USA where such good practices stand out as innovative examples of apprenticeship development in response to technological change in advanced manufacturing.

Implications for EU IVET policy

A number of implications for EU IVET policy should be highlighted that emerge from this study that may have been contributory factors in the development of recent EU initiatives, such as the European Alliance for Apprenticeship (launched in 2013 and supported by 27 EU Member States, all 5 candidate countries, all 4 EFTA countries (Iceland, Liechtenstein, Norway and Switzerland) and over 200 apprenticeship stakeholders), and in the results achieved in the framework of the tripartite Advisory Committee on Vocational Training, which led to a European Framework for Quality and Effective Apprenticeship, proposed by the European Commission in October 2017 (European Commission, 2017c) and agreed by the Council of the European Union in March 2018.[37]

At the same time, implications for EU industrial policy initiatives related to advanced manufacturing should also be highlighted. A step in this direction is the recent European Commission's Communication on the Digital Education Action Plan, which points to the need to invest in lifelong learning with an emphasis on digital skills in the context of 'a digital revolution' transforming many jobs and industries. With this objective in view, the Communication sets out a number of actions for the education, VET and higher education systems to cope with the digital transformation of the industry and the society (European Commission, 2018).

As regards the support of high-quality and efficient apprenticeship systems and practices, the study has shown that there are significant differences with regard to the systemic, regulatory as well as governance dimension of apprenticeship in general, and more specifically within the manufacturing sector. The study has also pointed to differences across national systems in terms of the attractiveness of apprenticeships for enterprises, the number of apprenticeship programmes, the quality of on-the-job as well as off-the-job training, and elements related to governance. Against this background, the study points to a need to provide guidance and orientation for the development of apprenticeship systems at transnational level, including certain minimum standards.

The Council Recommendation establishing a European Framework for Quality and Effective Apprenticeships aims to provide a coherent framework based on a common understanding of what defines quality and effective apprenticeships. Various aspects are proposed for inclusion.

The criteria for learning and working conditions would include:

- a written agreement between the employer, the apprentice and the VET institution;
- learning outcomes;
- pedagogical support;
- the workplace component;
- pay and/or compensation;
- social protection;
- work, health and safety conditions.

The criteria for framework conditions would include:

- the regulatory framework;
- the involvement of social partners;
- support for companies;
- flexible pathways and mobility;

37 See http://www.consilium.europa.eu/en/press/press-releases/2018/03/15/quality-and-effective-apprenticeships-council-adopts-european-framework/pdf

- career guidance and awareness raising;
- transparency;
- quality assurance and graduate tracking.

It is too early to assess the impact of this proposed European Council Recommendation. First, a Recommendation is non-binding, although it does of course carry a certain political authority. Second, it remains to be seen what measures EU Member States would be willing to introduce at the national level. Third, it also remains to be seen what form the implementation of these measures would take in each Member State. However, it is important to note that the implementation will be monitored by the European Commission, with the support of the tripartite Advisory Committee on Vocational Training, and progress will be reviewed by the Council in 2021. Moreover, in the intervening period, the European Commission is preparing a set of apprenticeship support services designed to facilitate, reform and/or improve apprenticeship systems.

The Recommendation sends out an important message, not only to EU Member States and candidate countries that are in the process of developing apprenticeship systems, but to other competing industrialised countries such as Australia and the USA. The message is that apprenticeships constitute an important form of IVET which provides young people with high-quality training and an opportunity to make the transition from formal education to the world of work, and provides employers with a highly skilled workforce. In addition, it signals a contribution to a policy objective of encouraging the development of jobs, growth and investment.

By focusing on the manufacturing sector and the challenges emerging from advanced manufacturing technologies and production processes and methods, this study has shown that apprenticeship training is an efficient way of equipping young people for a career in manufacturing and for providing enterprises with a highly qualified workforce. Apprenticeship systems provide companies with young talents that acquire general occupational qualifications and skills, as well as specific skills and competences required by the company.

This clear contribution of apprenticeship to a highly qualified workforce and to the competitiveness of companies in the manufacturing sector is strongly acknowledged in countries such as Denmark and Germany, as well as in France (as to higher apprenticeships). It is also increasingly acknowledged in Ireland as an orientation of reform. However, due to the various barriers highlighted in Chapter 4, the added value of apprenticeship in Italy, Australia and the USA is mainly acknowledged by some large companies, sector-specific research and IVET institutions.

EU-level initiatives addressing advanced manufacturing technologies or fostering transformation processes towards digitising industries should have a strong component related to IVET and apprenticeship programmes. This currently is not the case. For example, in the context of the work of the European Commission to provide a platform of National Initiatives on Digitising Industry launched in March 2017 at the Digital Day in Rome,[38] there are no links to modernising and adjusting VET provision and apprenticeship systems.

This illustrates that strengthening the links between industrial and technology policy and the IVET system must be regarded as an important success factor. This study has shown that in those countries that have a highly developed, efficient and successful apprenticeship systems, business interests (as well as employee involvement) are also playing a key role.

Therefore, it is suggested that recent EU-level initiatives in the context of the Renewed EU Industrial Policy Strategy – such as the organisation of an annual Industry Day and the establishment of a High-level Industrial Roundtable (Industry 2030) – should also include as an integral part a section addressing VET requirements, roles and tasks, including apprenticeship programmes. This should be done in cooperation with relevant stakeholders including the Platform of European Associations of VET Providers.

A further implication for EU IVET policy relates to linkages as well as transitions between initial and higher VET in general and apprenticeship in particular. Such linkages, as well as further and lifelong training and learning, are becoming more important as a result of the transformation towards 'advanced', 'smart' or 'digitised' manufacturing. At the same time, improving (or establishing) linkages between initial and higher as well as further VET are a challenge in all the countries analysed. There is a need to differentiate between various forms of higher apprenticeship, and to foster and exchange practices and innovative approaches of higher apprenticeship, in the manufacturing sector that build on the strengths and success factors identified as crucial for apprenticeship systems.

38 For additional information, see https://ec.europa.eu/digital-single-market/en/news/european-countries-join-forces-digitise-industry

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Annex 2: List of organisation names and acronyms

Abbreviation	Definition in original language	Definition in English
AMWU		Australian Manufacturing Workers' Union
BAVC	Bundesarbeitgeberverband Chemie eV	Federation of Chemical Employers' Associations
BIAC		Business and Industry Advisory Committee to the OECD
BIBB	Bundesinstitut für Berufsbildung	Federal Institute for Vocational Education and Training
BMAS	Bundesministerium für Arbeit und Soziales	Federal Ministry of Labour and Social Affairs
BMBF	Bundesministerium für Bildung und Forschung	Federal Ministry of Education and Research
BMWi	Bundesministerium für Wirtschaft und Energie	Federal Ministry for Economic Affairs and Energy
Cedefop	Centre européen pour le développement de la formation professionnelle	European Centre for the Development of Vocational Training
CEEP	Centre européen des entreprises à participation publique et des entreprises d'intérêt économique général	European Centre of Employers and Enterprises providing Public Services
CFA	Centre de Formation d'Apprentis	Apprentice Training Centre
CGIL	Confederazione Generale Italiana del Lavoro	Italian General Confederation of Labour
CISL	Confederazione Italiana dei Sindacati dei Lavoratori	Italian Confederation of Trade Unions
CNEFOP	Conseil national de l'emploi, de la formation et de l'orientation professionnelle	National Council for Employment, Training and Vocational Guidance
CNI	Conseil national de l'industrie	National Council of Industry
CPC	Commissions Professionnelles Consultatives	Professional Advisory Commissions
DI	Dansk Industri	Confederation of Danish Industry
ETUC		European Trade Union Confederation
IG BCE	Industriegewerkschaft Bergbau, Chemie, Energie	Trade Union for the Mining, Chemical and Energy industries
IG Metall	Industriegewerkschaft Metall	German Metalworkers' Union
INAPP	Istituto Nazionale per l'Analisi delle Politiche Pubbliche	National Institute for the Analysis of Public Policies
IOE		International Organisation of Employers
ILO		International Labour Organization
ITUC		International Trade Union Confederation
MISE	Ministero dello Sviluppo Economico	Ministry of Economic Development
MIUR	Ministero dell'Istruzione, dell'Università e della Ricerca	Ministry of Education, Universities and Research
MLPS	Ministero del Lavoro e delle Politiche Sociali	Ministry of Labour and Social Policy
NIMS		National Institute for Metalworking Skills [USA]
OECD		Organisation for Economic Cooperation and Development
SIPTU		Services Industrial and Professional Union [Ireland]
TUAC		Trade Union Advisory Committee to the OECD
ÜBS	Überbetriebliche Berufsbildungsstätten	industry-wide vocational training centres

Abbreviation	Definition in original language	Definition in English
UEAPME	Union Européenne de l'Artisanat et des Petites et Moyennes Entreprises	European Association of Craft, Small and Medium-sized Enterprises
UGL	Unione generale del Lavoro	General Workers' Union
UIL	Unione Italiana del Lavoro	Italian Union of Labour
UIMM	Union des industries et des métiers de la métallurgie	Union of Metallurgy and Mining Industries
USMAP		United Services Military Apprenticeship Program [USA]
VDMA	Verband deutscher Maschinen- und Anlagenbau eV	Association of German Mechanical and Plant Engineers
ZVEI	Zentralverband Elektrotechnik und Elektronikindustrie	Association of the Electrical Engineering and Electronics Industry

Annex 3: List of stakeholders consulted

Country	Type of organisation	Name of organisation	Position
Denmark	Ministry responsible for VET	Undervisningsministeriet – Styrelsen for Undervisning og Kvalitet	Responsible for apprenticeships in industry
	Public agency/VET provider	Mercantec	Head of department for technology
	Employer organisation	Dansk Industri	Head of section
	Trade union organisation	Dansk Metal	Head of education and training secretariat
	VET expert/research institute	Professionshøjskolen Metropol – nationalt Center for erhvervspædagogik	Deputy head of department/training expert
France	Ministry responsible for VET	Ministère du travail, de l'emploi, de la formation professionnelle et du dialogue social	Head of the Training and Qualification Policies unit
	VET provider	Agence nationale pour la formation professionnelle des adultes (AFPA)	Director of observatory 'Jobs and Qualifications'
	Employer organisation	UIMM	Adviser, responsible of the training centres, general delegation employment and training
	Trade union organisation	Fédération Générale de la Métallurgie et des Mines – affiliated to French Democratic Confederation of Labour (CFDT)	Confederal Secretary in charge of industrial policies
	VET expert/research institute	CNEFOP	General Secretary
Germany	Ministry responsible for VET	BMBF	Head of Department Vocational Education and Training
	Employer organisation	Gesamtmetall	Head of VET department
	Trade union organisation	IG BCE	VET expert
	VET expert/research institute	BIBB	VET expert on effects of digitalisation
	VET expert/research institute	BIBB	Apprenticeship expert/ comparative analysis
Ireland	Government agency responsible for apprenticeships	Apprenticeship Council	Member of the Board of the Apprenticeship Council
	Employer organisation	IBEC	Head of Training and Skills
	Employer	Jones Engineering Group	Member of the Board of the Apprenticeship Council
	Trade union	SIPTU	Sector Organiser, Electronics, Engineering & Industrial Production
	Government agency responsible for VET	Further Education and Skills Service	Director, Apprenticeship and Construction Services
	Trade union	Technical Engineering & Electrical Union	General Secretary

Country	Type of organisation	Name of organisation	Position
Italy	Ministry responsible for VET	MLPS	Executive – National Agency for Active Labor Policies (ANPAL)
	Public agency/VET provider	INAPP (Isfol)	Head of the Research Group on Skills and Qualifications
	Employer organisation	Confindustria	Executive – Labour, Welfare and Human Capital
	Trade union organisation	CGIL	Member of the National Secretariat
	VET expert/research institute	ADAPT	President of Adapt; Professor of Pedagogy of Labour; VET and Apprenticeship Expert
Australia	Ministry responsible for VET	Commonwealth Department of Education and Training	Director, Apprenticeships and Youth Policy section
	Peak body for public VET providers	TAFE Directors Association (TDA)	Chief Executive Officer
	Peak body for group training employers	National Apprentice Employment Network	Executive Officer
	Public agency/VET provider	Australian Council for Private Education and Training	Chief Executive Officer
	Employer organisation (manufacturing)	Ai Group (Australian Industry Group)	Director, Workforce Development
	Trade union organisation	Australian Manufacturing Workers Union	National Coordinator, Skills, Training and Apprenticeships Policy
	Contracted organisation with responsibility for competence standards and qualifications for manufacturing vocational training	Innovation and Business Skills Australia	CEO, in charge of body that resources changes to manufacturing training package
	Industry association covering 3D printing	Australian 3D Manufacturing Association (A3DMA)	CEO, in charge of developing projects and contributing advice on future skills needs
USA	**Ministry responsible for VET but not apprenticeship**	**Department of Education**	**Former Deputy Assistant Secretary, Office of Vocational and Adult Education**
	Employer organisation	**National Association of Manufacturers**	**Vice-president, Strategic Initiatives, Manufacturing Institute**
	Trade union organisation	**United Auto Workers**	**Coordinator, National Joint Apprenticeship Committee**
	VET expert/research institute	**Office of Apprenticeship**	**Regional Director**

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Apprenticeships combining alternating periods at the workplace and in training institutions are well suited to providing young people with an entry point into the labour market and to supplying enterprises with skilled workers. This report examines apprenticeship systems and practices in the manufacturing sector in five EU Member States (Denmark, France, Germany, Ireland and Italy) and two countries outside Europe (Australia and the USA), exploring reform processes in response to new skill requirements arising from technological change. The report highlights the variety of approaches to modernising national apprenticeship systems and sheds light on the many challenges posed by technological change. A promising avenue is to establish a coherent industrial policy framework that prioritises skills acquisition, supports the transition from initial to higher vocational and educational training, and assigns a central role to apprenticeship training in the context of the modernisation of manufacturing.

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