International Labour Organization

Skills shortages and labour migration in the field of information and communication technology in Canada, China, Germany and Singapore

"The Future of the Work in ICT" Project

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ILO

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Preface

The International Labour Organization (ILO) is the United Nations specialized agency dedicated to advancing opportunities for women and men to obtain decent and productive work in conditions of freedom, equity, security and human dignity. The ILO Sectoral Policies Department promotes decent work by supporting the Organization's tripartite constituents, namely governments, employers and workers, in creating opportunities and addressing challenges in 22 different economic and social sectors at the global, regional and national levels.

Information and Communication Technology (ICT) is a key economic sector and generator of jobs and may be considered the backbone of the digital economy across all sectors. It increases productivity and has a profound impact on business processes, tasks and the organization of work across the entire economy. The ICT sector represents an opportunity for future employment, particularly for young people.

Recent global developments, namely the coronavirus disease (COVID-19) pandemic, reflect the strong role of ICT in the global economy. For example, educational institutions and workplaces have been able to maintain continuity by relying on digital technologies. Digital health technology has provided successful and innovative solutions during the pandemic. The digital economy will also play a key role in "building back better" following the pandemic.

Rapid technological development can also pose several challenges, such as labour market displacements and increased inequalities. One potential solution for addressing those issues is investing in the skills and capabilities of people. In many countries, the global ICT sector is facing a shortage of skilled ICT workers. A lack of skilled labour will constrain future growth and job creation in the sector. But with the right policies in place – including targeted investments in education and skills training in the digital economy, and the efficient management of labour migration flows – the digital economy can make a significant contribution to advancing decent work and inclusive economic growth at the global, regional and national levels.

This report is the second outcome of an ILO development cooperation project entitled "The Future of Work in Information and Communication Technology (ICT)". This global research project focuses on the anticipated need for skilled workers and strategies for addressing labour shortages, including the scaling up of investments in ICT education and training, and more efficient management of ICT specialist migration flows.

The project strengthens the ILO's knowledge base regarding the future of work, skills development and effective lifelong learning for all. This is in line with the ILO Centenary Declaration for the Future of Work, adopted in June 2019, which calls for, "promoting the acquisition of skills, competencies and qualifications for all workers throughout their working lives". The project also contributes to the achievement of several Sustainable Development Goals, particularly Goal 4 on "ensuring inclusive and equitable quality education and promote lifelong learning opportunities for all", Goal 5 on "achieving gender equality and empowering all women and girls", and Goal 8 on "promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all".

This report was prepared by external consultant Nicola Düll, with the supervision of Shreya Goel, Junior Project Officer, Hitomi Takeuchi-Nakagome, Project Manager, Casper N. Edmonds, Head of the Extractives, Energy and Manufacturing Unit, Akira Isawa, Deputy Director, and Alette van Leur, Director, Sectoral Policies Department. External consultants, Elizabeth Fagan and Rebekka Yates edited the report.

Substantial technical contributions were provided by national consultants including Pang Shi, Chinese Academy of Personnel Science in China, Zhenzhen Ye and Alexandra Cutean, Information and Communications Technology Council (ICTC) in Canada, Tim Vetter, Economix Research & Consulting in Germany, and Zhihan Yeo, SGTech and Carolyn Poon, the Seed Consulting Group LLP in Singapore. A sincere thank you is also due to Kevin Cassidy, Director, and Jennifer Mansey, former Public Policy and Communications Officer at the ILO Office for the United States, Tomoko Nishimoto, former Regional Director for Asia and the Pacific, and Rakawin Leechanavanichpan, Programme Officer at the ILO Regional Office for Asia and the Pacific, Claire Courteille-Mulder, Director, and Xiaochu Dai, Deputy Director at the ILO Country Office for China and Mongolia, and Annette Niederfranke, Director at the ILO Country Office for Germany, for their valuable contributions and support in preparing for and carrying out the country-level fact finding missions.

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Abbreviations and acronyms

ACFTU	All-China Federation of Trade Unions
AI	Artificial Intelligence
AKDB	Anstalt für Kommunale Datenverarbeitung in Bayern (Institute for Municipal Data Processing in Bavaria)
ASEAN	Association of South East Asian Nations
BA	Bundesagentur für Arbeit (Federal Employment Agency, Germany)
BAMF	Bundesamt für Migration und Flüchtlinge (Federal Office for Migration and Refugees, Germany)
BCIT	British Columbia Institute of Technology
BDA	Bundesvereinigung der Deutschen Arbeitgeberverbände (Confederation of German Employers' Associations)
BiBB	Bundesinstitut für Berufsbildung (Federal Institute for Vocational Education and Training, Germany)
BMAS	Bundesministerium für Arbeit und Soziales (Federal Ministry of Labour and Social Affairs, Germany)
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research, Germany)
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy, Germany)
CEC/CEDA	China Enterprise Confederation/China Enterprise Directors Association
COPS	Canadian Occupational Projection System
DGB	Deutscher Gewerkschaftsbund (German Trade Union Confederation)
EDB	Economic Development Board, Singapore
ESDC	Employment and Social Development Canada
GDP	Gross domestic product
IAB	Institut für Arbeitsmarkt- und Berufs–forschung (Institute for Employment Research, Germany)
ICT	Information and communication tech-nology
ICTC	Information and Communications Tech-nology Council, Canada
IMDA	Infocomm Media Development Authority, Singapore
INSEAD	Institut Européen d'Administration des Affaires
IOM	International Organization for Migration
IoT	Internet of Things
IRCC	Immigration, Refugees and Citizenship Canada
ISED	Innovation, Science and Economic Development Canada
IW	Institut der deutschen Wirtschaft (German Economic Institute)
KldB 2010	Klassifikation der Berufe 2010 (German Classification of Occupations 2010)
MOHRSS	Ministry of Human Resources and Social Security, China
MOM	Ministry of Manpower, Singapore
MUAS	Hochschule für Angewandte Wissen–schaften München (Munich University of Applied Sciences)
NTUC	National Trades Union Congress, Singapore
NUS	National University of Singapore
OECD	Organisation for Economic Co-operation and Development
PwC	PricewaterhouseCoopers
R&D	Research and Development
SIT	Singapore Institute of Technology
SMEs	Small and medium-sized enterprises
SSG	SkillsFuture Singapore
SSIA	Singapore Semiconductor Industry Association
STEM	Science, Technology, Engineering and Mathematics
TeSA	TechSkills Accelerator, Singapore
TTAB	Tech Talent AssemBly, Singapore
TUM	Technische Universität München (Technical University of Munich)
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
VDI	Verein Deutscher Ingenieure (The Association of German Engineers)
VET	Vocational Education and Training
WSG	Workforce Singapore
ZAV	Zentrale Auslands- und Fachvermittlung (International Placement Service, Germany)

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Executive summary

Information and Communication Technology (ICT) industries have seen impressive growth over the past few years. As ICT becomes integral to other sectors, transforming the way they work, the ICT sector itself is experiencing rapid change. Digitalization is reshaping economies across the world, including those of Canada, China, Germany and Singapore, and it is a significant driver of increasing demand for ICT specialists – both in the ICT sector and across many other sectors of the economy.

New digital technologies present tremendous opportunities for economies and societies. They can help broaden access to goods and services and increase efficiencies. At the same time, rapid technological development can cause displacements in the labour market and have impacts on work-life balance and social protections. Technological development will also have an impact on required skill sets, highlighting the importance of investing in lifelong learning (UNCTAD, 2019).

Many parts of the world are facing potential shortages of ICT specialists, and those shortages may negatively impact a country's economic growth and development efforts. The insufficient supply of ICT skills has therefore become a major concern for governments, and employers' and workers' organizations.

However, with the right policies in place, particularly those targeted at investment in quality education and training, and more efficient governance of labour migration, the digital economy could make a significant contribution to advancing decent work, enhancing the capabilities of people, and promoting inclusive economic growth at the global, regional and national levels.

The aim of this report is to provide a more comprehensive understanding of the most critical aspects of the future of work in the ICT sector by analysing the possible interactions among technological changes, education and training, employment, labour migration and the organization of work and production in four countries: Canada, China, Germany and Singapore. The report specifically examines (a) trends in the ICT sector and ICT labour markets; (b) the potential demand for ICT jobs and anticipated shortages of skilled workers in the digital economy, as well as approaches for improving the education and training of ICT workers; and (c) factors affecting the labour migration of highly-skilled ICT workers.

The report is comprised of four chapters. Chapter 1 provides an overview of the development of the ICT sector and ICT labour markets in Canada, China, Germany and Singapore. Chapter 2 assesses the extent of skills shortages and skills mismatches for ICT specialists, provides a brief review of recent policies in that area and analyses the education sector's capacity to address those challenges. Chapter 3 analyses the international labour migration of ICT specialists by examining incentives and barriers for migrants working abroad. The final chapter outlines key findings and presents possible policy responses for governments, education and training institutions, and employers' and workers' organizations.

ICT sector and labour market trends in Canada, China, Germany and Singapore

The key technological trends and applications that have been driving the digital transformation of the economies of Canada, China, Germany and Singapore include: artificial intelligence (AI), big data, machine learning, blockchain technology, financial technology (fintech), information technology (IT) security, cloud computing, the Internet of Things (IoT), automation technologies, robotics, 3D-printing, virtual reality, augmented reality, digital platforms, automated driving, smart city and smart home technologies, and mobile applications. Such technologies and trends are often highly interconnected.

Highlights

a. The ICT sectors of all four countries have grown significantly. In Canada, Singapore and China, the ICT sector grew faster than the overall economy.

b. Employment in the ICT sector represented the largest share of total employment in the labour markets of Singapore and Canada, followed by Germany and China. Employment in the sector has been growing steadily in all four countries.[1]

1 Since available data are not fully comparable because the definition of ICT specialists varies by country, these are estimates.

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c. Sectors other than the ICT sector employ a large share of ICT specialists working in other areas of the digital economy. More than 50 per cent of ICT specialists in Canada, Germany and Singapore were employed in sectors other than the ICT sector and as digitalization continues to transform all sectors of the economy, the share of ICT specialists is expected to increase in other non-ICT sectors.

d. The proportion of female ICT specialists was well below economy-wide averages across the labour force: women comprised approximately 30 per cent of IT and media workers in Singapore in 2018; 25 per cent of ICT specialists in Canada in 2019; and only 17 per cent of ICT specialists in Germany in 2018. While no official data are available for China, research mission interviews suggested that there might be more men than women working as ICT specialists in that country.

e. ICT specialists had higher levels of educational attainment than the average worker. In Singapore, two thirds of ICT specialists hold a university degree, while in Canada that figure is 55 per cent and in Germany it is 37 per cent.

f. ICT specialists tended to have higher than average levels of income. For example, in Canada, ICT workers earned 49.4 per cent more than the economy-wide average, with the highest earners working in the wholesaling[2] and software and computer services subsectors.

g. Research suggested that ICT specialists worked relatively long hours. The reasons for this varied from country to country. However, project-related fluctuation, such as higher workload close to a project deadline or unexpected increase in the number of projects, was one of the most frequently cited reasons.

h. Governments in all four countries play a major role in promoting the digitalization of the economy and implementing strategies to secure the supply of skilled labour. Governments monitor future skills needs and invest in digital infrastructure, innovation and skills development.

i. Governments, employers' and workers' organizations play a crucial role in addressing skills shortages, promoting skills development and managing labour migration in the field of ICT. Several examples of collective bargaining in the ICT sector can be found in Germany. However, in the other countries examined, collective bargaining is less widespread in the ICT sector than in other sectors of the economy. There are several reasons for this, including relatively high wages paid in the ICT sector and to ICT specialists working in other sectors.

Education and skills development

Surveys conducted by employers' and workers' organizations indicate that skills shortages have been severe and are predicted to remain a pressing issue in the future. Canada, China, Germany and Singapore face shortages of specialists in the area of new technologies able to fill corresponding job roles. In particular, there are severe shortages of software developers and programmers in the four countries.

Highlights

a. Long-term projections by the Governments of Canada, Germany and Singapore indicate that demand for ICT specialists will increase significantly over the next few years.

b. Demand for workers with skills in the area of new technologies has been rising rapidly. For example, AI is one of the major technologies and trends generating such demand, while sought after skills in the area of cloud computing, big data and cyber security are increasing in all four countries.

c. As both technological complexity and the adoption of digital technologies across sectors continue to evolve, the ability to work in interdisciplinary fields and to have some knowledge of other study fields is becoming increasingly important in all four countries.

d. In the light of a need to handle a wide variety of work processes and customers, implementing digitalization requires good communication skills and high-level learning capacity. It is widely acknowledged that soft skills have become increasingly important for ICT specialists. According to individual surveys conducted in Canada, Germany and Singapore, a significant share of employers expressed the view that ICT specialists were lacking soft skills, such as communication skills.

e. In order to close skills gaps between skills acquired at universities or vocational institutions and skills required by the industry, internships are a popular means for work-based learning. In all four target countries, internships often take place under the supervision of educational institutions. In Canada, co-op programmes are widespread and allow students to include a few months of work experience as a part of their tertiary education. An increasing number of universities in China have also made internships mandatory.

f. The speed at which technologies in ICT are evolving means that, for ICT specialists, the need to regularly update their skills is greater than it is

2 This includes wholesale of computers, computer peripheral equipment, software, and electronic and telecommunication equipment and parts

for many other occupational groups. ICT specialists can engage in continuous training by learning from co-workers, learning by doing and keeping up to date with industry trends, as well as from formal programmes offered by companies and external providers.

g. Lifelong learning in relation to ICT has the potential to facilitate and accelerate digital transformation, support national innovative capacity, facilitate occupational mobility, respond to challenges arising from demographic changes, and provide equal access to skills development.

h. In all four countries, employers' and workers' organizations play a key role in designing curricula for post-secondary, tertiary and continuous education. Educational institutions collaborate with industry to gain insight into future skills needs, in addition to helping students gain practical experience.

i. ICT skills training is strongly gender biased. In 2016, women comprised only one third of graduates from ICT tertiary education programmes in Singapore and 30 per cent of those in Canada, while in Germany that number was only 18 per cent. Concerted efforts have been made at all education levels to promote girls' interest in the field of ICT, including at the primary school level.

International labour migration of ICT specialists

International labour migration of ICT specialists to Canada, China, Germany and Singapore has increased due to high labour demand and skills shortages.

Highlights

a. In Canada and in Germany, the share of foreign-born ICT specialists is higher than the average across the labour market, while in Singapore that number is about equal to the overall average. In China, the percentage of skilled and highly-skilled foreign workers, including ICT specialists, is low.

b. Incentives for ICT specialists to emigrate from less developed countries to Canada, China, Germany and Singapore include higher earnings and better social welfare provisions such as greater access to health care services, a high-quality education system and the destination country's infrastructure advantages. The opportunity for long-term career development, in which international exposure plays a significant role, is also a decisive factor for labour migration. Canada provides counselling, pre-arrival and post-arrival services for migrant workers, while Germany has increased measures to facilitate employment placement.

c. Lack of recognition of foreign qualifications and inadequate language skills are among the barriers faced by migrating ICT specialists. Even when immigrants do not require knowledge of the local language for work, inadequate language skills hinder their prospects for integration into society. In some instances, migration policies and long and complex visa procedures are noted as a barrier to ICT migrants working in the four countries. Canada, China, Germany and Singapore have recently introduced measures to facilitate the migration of ICT specialists.

d. The migration of students is often the first entry into a country's labour market. In 2011, approximately half of the migrant workers employed in Canada as ICT specialists had also studied in Canada. In Germany, the proportion of international students in ICT study fields was double of the proportion of international students studying in other fields. In addition to being a country of origin for ICT students, Singapore was also a top destination for international students in Asia. On the other hand, China has traditionally been an origin country, with numbers of Chinese overseas on the rise and over one million students studying abroad in 2014.

e. The return migration of ICT specialists is an important topic for China and Singapore. Reasons for returning included better job opportunities after completing an education abroad, diverse research opportunities in both academia and industry, and family-related considerations.

Introduction

Box 0.1: Digital technologies during the COVID-19 pandemic

Digital technologies have played a crucial role in ensuring societies remain as functional as possible during the COVID-19 pandemic. For many, these technologies have enabled remote work and distance learning. According to the World Health Organization, digital health technology has provided successful solutions for population screening, infection tracking, prioritizing resource use and allocation and designing targeted responses. The pandemic has also reinforced digital trends in commerce, supply chains and finance.

As highlighted by the World Economic Forum, COVID-19 has demonstrated the importance of digital readiness (World Economic Forum, 2020). Investing in the necessary infrastructure and taking an inclusive and human-centred approach to technology will be critical as the post-pandemic world rebuilds.

Digitalization is having a profound impact on economies and societies worldwide. Not only is the ICT sector itself changing rapidly[1], but ICT services and products are also becoming an integral part of other sectors, including financial services and manufacturing. In the future, digitalization is also expected to transform sectors such as education, agriculture and health care. Digital technologies present an enormous opportunity for economies and societies, inter alia by expanding access to good and services, and fostering efficiencies. Such technologies have proven to be an important tool for continuity and resilience during times of crisis, including during the COVID-19 pandemic (see Box 0.1).

On the other hand, rapid technological change also poses several challenges. There are concerns of job losses in the future due to automation and AI, widening of the gender gap in digital technologies and an increase in discrimination and inequalities due to inherent biases in algorithms. Furthermore, access to more advanced production technologies remains highly unequal. The adoption of technologies will depend on a number of factors, including a country's economic and social development, its placement within global supply chains, the availability of digital infrastructure, competition and new markets, societal acceptance of technologies and the availability of highly-skilled labour.

ICT specialists do not easily fit into a defined occupational category. Current classifications and occupational subgroups may not capture new occupational groups that are emerging as technology continues to develop. Those new occupations may include AI-related occupations, big data analysts and other new technology-based jobs.

This report uses the definition of "ICT specialist" developed by the Organization for Economic Co-operation and Development (OECD) and Eurostat. According to International Standard Classification of Occupations (ISCO) – 08, OECD and Eurostat, ICT specialists are highly-skilled workers, and include ICT services managers, electrotechnology engineers, ICT professionals, information and communications technicians (see Annex Table A2). However, the definitions of "ICT specialist" used in statistical analyses differ for each of the four target countries examined here, based on their respective national classification systems for occupations. Therefore, data are not entirely comparable.

The ICT sector and relevant occupations have changed rapidly in recent years and are expected to continue to do so in the future (see Annex Table A1 and A2). Highly-skilled ICT jobs are increasingly becoming an integral part of other economic sectors, and those jobs require transferable skill sets. The lack of reliable, detailed and comparable data regarding ICT occupations makes it difficult to undertake cross-country comparisons of ICT specialist employment – both within the ICT sector and across other sectors.

However, numerous studies indicate that many parts of the world are facing a potential shortage of ICT specialists and that those shortages may have negative impacts on a country's economic growth and development efforts. The inadequate supply of ICT skills has therefore become a major concern for governments, employers and workers.

1 The ICT sector includes ICT manufacturing, ICT trade, ICT services, telecommunications, computer programming, consultancy and related activities, data processing, hosting and related activities, web portals, repair of computers and communication equipment. For a detailed definition, see Annex Table A1).

When seeking to promote skills development, options include: investing in the education and training of highly-skilled workers, including both initial education and training as well as upskilling and reskilling later on; promoting occupational mobility and identifying potential in mid-career and older workers; encouraging foreign direct investment in countries with a large supply of ICT specialists and outsourcing operations to such locations; enabling efficiently governed labour migration; and supporting women workers by removing gender barriers and providing incentives for women to enter ICT occupations.

Objective

The objective of this report is to deepen understanding of:

a. Trends in the ICT sector and ICT labour markets;

b. The potential demand for ICT jobs and anticipated shortages of skilled workers in the digital economy;

c. Approaches for improving the education and training of ICT workers;

d. Factors affecting the labour migration of highly-skilled ICT workers.

In addition, gender issues are considered in a cross-cutting manner.

The report will examine the following in detail:

- Existing approaches to ICT education and skills development in Canada, China, Germany and Singapore, and provide recommendations as to how those initiatives and policies may be scaled-up to promote decent work opportunities and economic growth.
- Key issues and best practices for effective governance of ICT labour migration, and how migration can benefit origin and destination countries and the ICT workers themselves.

Scope

This report is the second in a series of three reports. While there are several aspects to promoting decent work opportunities in the digital economy, this report specifically focuses on skills shortages, skills development and labour migration in ICT fields in Canada, China, Germany and Singapore. Those four countries have all invested in the ICT education and skills development of their workers. As demand for ICT specialists has risen, all four countries have experienced increasing shortages of highly-skilled ICT workers in both their domestic ICT sectors and across other related sectors.

In this report, Canada, China, Germany and Singapore were chosen as target countries for the following reasons:

- ICT services are driving the digitalization of those countries' economies. The most recent technological trends in the area of digitalization are challenging economic transformation and generating a high demand for ICT specialists.
- The semiconductor industry – a globally growing and key innovative sector among ICT manufacturing industries – is undergoing rapid development in China, Germany and Singapore. Innovations in ICT manufacturing outputs and ICT services are critical for the manufacturing industry.
- Within the four countries, digitalization is taking place in different economic growth models. For example, China has been extremely dynamic in the area of skills development in recent years and is seeking to move from a low-skilled production model towards a highly-skilled and innovative economy. Economic transformation has also been impressive in Singapore over the past several decades. While Germany is a highly developed and knowledge-based industrialized country with strong capacities in engineering traditionally and ICT more recently, Canada is rich in natural resources but has been moving towards a knowledge-based economy.
- Skills development programmes for ICT specialists in each of the four countries have begun to develop approaches for meeting the need for more varied skills and the fostering of interdisciplinary and entrepreneurial thinking and innovation.
- In all four countries, attracting migrant ICT specialists is one approach countries have used to overcome skills shortages.

Methodology

This report is based on an extensive literature review, background reports prepared by national consultants in each country, and four week-long research missions to Ottawa and Vancouver in Canada, Beijing and Shenzhen in China, Berlin, Bonn, Munich and Nuremberg in Germany and to Singapore. In total, approximately 90 interviews were conducted with representatives from governments, training institutions, universities, research organizations, six employers' and eight workers' organizations, recruitment agencies and private companies from the ICT sector (see the Annex Table A11 for a list of interviewees). The information provided by those interviewed enriched the assessment of current and future trends and challenges faced by the industry and workers.

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Due to the lack of comparable and up-to-date data, direct quantitative comparison of the qualifications and skills mismatch situation among the four countries was not possible. For Canada, detailed labour force survey data and national data from Statistics Canada were available; for Germany, detailed administrative data in addition to some labour force data were available; for China and Singapore, detailed labour force data were not publicly available.

Report structure

The report is divided into four chapters. Chapter 1 provides an overview of the development of the ICT sector and the ICT labour markets in Canada, China, Germany and Singapore. Chapter 2 assesses the extent of skills shortages and skills mismatches for ICT specialists. It also provides a brief review of recent policies, with an analysis of the education sector's capacity to address skills mismatches. Chapter 3 analyses the international labour migration of ICT specialists by examining incentives and barriers for migrants working abroad. Lastly, Chapter 4 outlines the key findings and proposes possible policy responses for governments, education and training institutions, and employers' and workers' organizations.

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1

Trends in the ICT sector and labour markets in Canada, China, Germany and Singapore

1.1 Digitalization

Across the world, digitalization is reshaping economies, including those of Canada, China, Germany and Singapore. Digitalization is a significant driver of increased demand for ICT specialists to work in the ICT sector and across many other economic sectors.

Out of 141 countries included in the World Economic Forum Global Competitiveness Report 2019, Singapore ranked as the world's most competitive economy based on the report's scoring factors (Score 84.8), Germany was in seventh (Score 81.8), Canada in fourteenth (Score 79.6), and China in twenty-eighth place (Score 73.9). Germany excelled in innovative capacity, in that it ranked first in that category, and it also ranked highly in terms of skills, at fifth place. Of the four economies, Singapore was ranked the most competitive in both the labour market and the ICT adoption indicator pillars. A possible explanation for this could be that as a city-State, Singapore is able to adopt technology at

Table 1.1 Rankings of the four countries according to the World Economic Forum Global Competitiveness Report, 2019

	Canada	China	Germany	Singapore
Overall rank	14	28	7	1
Innovation capability[1]	16	24	1	13
Skills[2]	12	64	5	19
Digital skills among active population	20	45	21	5
Labour market[3]	8	72	14	1
ICT adoption[4]	35	18	36	5

Source: Schwab, 2019

1 The innovation capability pillar includes: information based on survey and administrative data on the diversity of workforce, state of cluster development, international co-inventions, multi-stakeholder collaboration, scientific publications, patent applications, R&D expenditures, research institution prominence and buyer sophistication.
2 The skills pillar includes: information on mean years of schooling, extent of staff training, quality of vocational training, skillset of graduates, digital skills among active population, ease of finding skilled employees, school life expectancy, critical thinking in teaching and pupil to teacher ratio in primary education.
3 The labour market pillar includes: information on redundancy costs, hiring and firing practices, cooperation in labour-employer relations, flexibility of wage determination, active labour market policies, workers' rights, ease of hiring foreign labour, internal labour mobility, reliance on professional management, pay and productivity, the ratio of wage and salaried female workers to male workers and labour tax rate.
4 The ICT-adoption pillar includes: information on mobile cellular telephone subscriptions, mobile broadband subscriptions, fixed broadband internet subscriptions, fibre-optic internet subscriptions and internet users.

a faster pace than other countries examined (Schwab, 2019).

1.1.1 Technological trends

The technological trends driving the digital transformation of economies around the world, including those of Canada, China, Germany, Singapore, are often interconnected. For example, the IoT has the potential to connect many billions of objects around the world and create opportunities for automation and interaction in real time. Due to the way it processes data on an enormous scale and accelerates pattern finding, AI can improve the efficiency of decision making. Accelerated investment in and adoption of AI have been enabled by technological progress in the fields of machine learning, big data and cloud computing. The challenges and risks arising from digital transformation mean that countries are introducing national digital security strategies, which in turn generates demand for cyber security technologies (OECD, 2017a).

To summarize, key technological trends and their applications include: AI, big data, machine learning, blockchain technology, fintech, IT security, cloud computing, IoT, automation technologies, robotics, 3D-printing, virtual reality, augmented reality, digital platforms, automated driving, smart city and smart home technologies and mobile applications. Countries differ in their degrees of development and progress with such technologies and their applications in specific sectors of the economy, including financial services and the automotive industry (Bitkom, 2018; BMWi, 2017a; ICTC, 2019a; IW, 2019; SGTech, 2019; SSG, 2017a; Zhang and Chen, 2019).

1.1.2 Adoption of digital technologies across sectors

The past few years have seen impressive growth in certain ICT industries, particularly in China, which has become a world leader in a number of services, particularly easily digitalized ones, such as e-commerce, online payments and online car hailing (OECD, 2019b). China is setting its own technological standards and promoting new ones, including 5G mobile network technology. In addition, the Chinese authorities are placing great emphasis on fostering innovation in the field of AI, digital facial recognition and gaming (Shi-Kupfer and Ohlberg, 2019).

The China Academy of Information and Communication Technology (CAICT) has estimated that China's digital economy doubled between 2008 and 2016, accounting for 30 per cent of Gross domestic product (GDP) in 2016[5] (Zhang and Chen, 2019). The service sector was the most digitalized, with ICT services contributing 33 per cent of the sector's economic value in 2017. Within services sectors overall, the most ICT-intensive subsectors were financial services, entertainment and professional technical services. The most digitalized manufacturing sectors included advanced manufacturing, as in the areas of mechanical engineering, instrumentation and electrical equipment and machinery, for example (CAICT, 2017).

China has a strong demand for semiconductors and is the world's largest purchaser and importer of chips. Developing and strengthening the semiconductor industry is a high priority for the Chinese government (PwC, 2019). Some German companies also feature among market leaders in the semiconductor industry, while foreign direct investment has made it possible to set up development centres and production in Singapore (SSG, 2017a). Although Canada does not have any global players in the semiconductor industry, the country has produced two of the top 19 major AI semiconductor start-ups globally since 2005 (PwC, 2019).

In Canada, according to Information and Communications Technology Council (ICTC), SMAAC (social, mobile, apps, analytics, and cloud) technologies, which fall under the wider umbrella of the IoT, will continue to transform the Canadian digital economy (ICTC, 2019a). Blockchain, 3D printing and AI developments will have a significant impact on several economic sectors. For example, blockchain is expected to transform the financial services industry, retail and other sectors.

Firm-level surveys suggest that one fifth of commercial enterprises in Germany use big data (BMWi, 2017b), and that, despite increasing investments in recent years, huge untapped potential for the use of digital technologies remains (Arntz, Gregory and Zierahn, 2018). Furthermore, the speed at which new technologies are being adopted largely depends on the sector and on a company's size (Research interview with acatech, Germany).

According to a survey conducted by the Ministry of Trade and Industry of Singapore, the adoption of digital technologies increased between 2014 and 2016. However, this included the fact that most firms had adopted basic digital technologies such as internet and computer usage, a web presence and information and communication security. Over 50 per cent of the firms examined in the survey had adopted e-payments, but there remains much to be done with respect to the adoption of advanced digital technologies such as e-commerce, data analytics and IoT, particularly for small and medium-sized enterprises (SMEs) in Singapore (Ministry of Trade and Industry, 2019a).

5 This estimate was produced by applying a broad definition of the digital economy to national accounts.

contents

▶ 1.2 Trends in the ICT sector in Canada, China, Germany and Singapore

1.2.1 Overview

In all four countries, the ICT sector's share of GDP ranges between 4 and 6 per cent. However, data are not fully comparable since the definitions used by the national statistical offices in the respective countries and by the OECD vary.

In China, the value of the ICT sector[6] was 4.8 per cent of GDP in 2015 (OECD, 2019b). This included large parts of ICT manufacturing but excluded ICT trade. Canada's ICT sector accounted for 4.5 per cent of its total GDP in 2018 (ICTC, 2019a). In Germany, the ICT sector (excluding ICT trade) accounted for 4.2 per cent of the country's GDP in 2017[7], while in Singapore, the ICT services sector contributed 4.1 per cent of the total nominal value added to GDP in 2018 (Ministry of Trade and Industry, 2018). Data on ICT manufacturing are not available in Singapore. However, the electronics manufacturing industry, of which the semiconductor industry is an important part, accounted for 5.4 per cent of Singapore's GDP (SSG, 2017a).

1.2.2 Recent growth

Canada

Growth in the ICT sector has outpaced the total growth of the Canadian economy over the past five years. In 2018, the ICT sector grew by 3.7 per cent; 1.4 percentage points higher than growth across the Canadian economy as a whole, which grew by 2.3 per cent. The growth of the sector can be attributed to the software and computer services and ICT wholesaling subsectors, with 7.7 and 11.4 per cent average annual growth rates, respectively (Government of Canada, 2020).

China

ICT sector growth has been very high in China in recent years. For example, since 2014 growth in turnover in the telecommunication industry has been extraordinary, and stood at more than 60 per cent in 2016 (OECD, 2017b). China has become a global leader in key digital industries, including e-commerce and fintech. China accounts for over 40 per cent of global transactions in e-commerce, and the country's penetration rate for e-commerce is 15 per cent of total retail sales, compared to 10 per cent in the United States of America. In the area of fintech, Chinese companies account for more than 70 per cent of total global valuations. In 2016, the value of China's consumption-related mobile payments by individuals was 11 times the value of those in the United States (Zhang and Chen, 2019).

Germany

Between 2010 and 2018, gross value added (GVA) in the ICT sector had stronger growth than in other traditional industrial sectors of the German economy, such as the mechanical engineering and chemical industries. Between 2016 and 2017, GVA increased by 4 per cent (BMWi, 2018a), while GDP growth that year was 1.5 per cent.

Singapore

In Singapore, after two relatively weak years of real growth in 2016 (2.3 per cent) and 2017 (3.3 per cent), growth in the ICT service sector was at 6.0 per cent in 2018, almost twice the 3.2 per cent growth rate of the overall economy (Ministry of Trade and Industry, 2019).

▶ 1.3 Employment in the ICT sector in Canada, China, Germany and Singapore

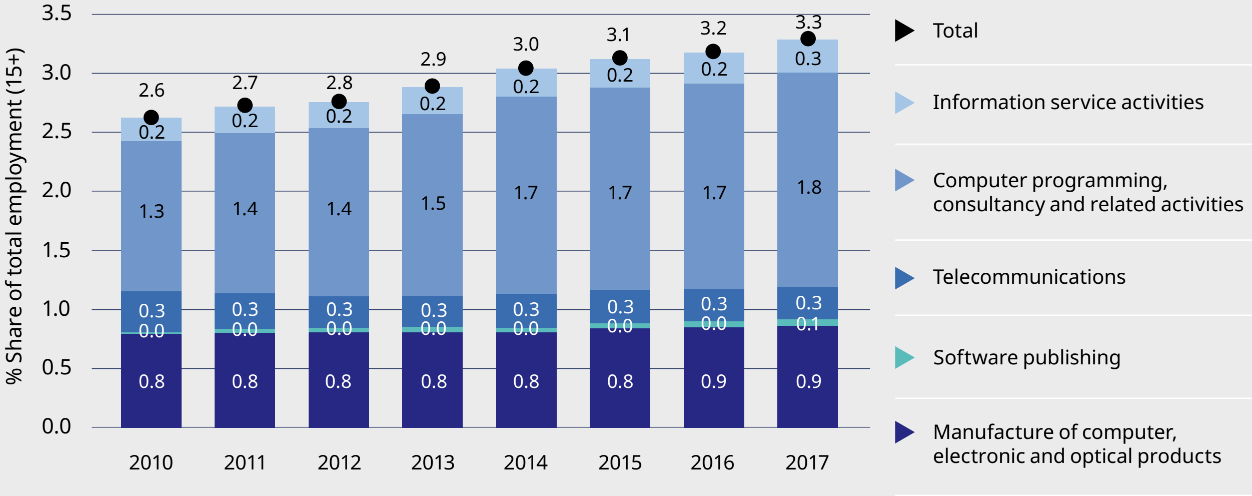
Of the four countries, employment in the ICT sector as a share of total national employment was the highest in Singapore, followed by Canada, Germany and China. However, the data among the four countries are not fully comparable because each country applies a different definition to the ICT sector.

In Canada, the ICT sector employed 686,700 professional workers in 2018, which was approximately 3.7 per cent of Canada's total employed population (ICTC, 2018). Of the total number of professionals, 531,700 were ICT specialists (ICTC, 2019). Employment in the

6 Definition of the ICT sector that takes the standard distinction between manufacturing and services into account, but does not include the manufacture of magnetic and optical media and ICT trade industries.
7 According to the Eurostat definition, which includes ICT manufacturing and ICT services (see Annex Table A1).

contents

▶ **Figure 1.1 Employment in ICT sectors – Germany, 2010-2017**



Source: ILO Labour Force Survey data

ICT sector increased by 3.8 per cent between 2017 and 2018, which was higher than employment growth in the overall economy, which stood at 1.3 per cent. This has been the trend for the past four years in Canada (ICTC, 2019).

In China, employment in the information transmission, computer service and software sectors – as classified by the National Bureau of Statistics of China – was 39.5 million workers in 2017, accounting for 2.2 per cent of China's total employment. Employment in these sectors has increased by 77 per cent since 2012 (OECD, 2019a). The share of ICT specialists as a proportion of total national employment would be higher if the ICT manufacturing and ICT trade sectors were also included.

In Germany, employment in the ICT sector[8] increased steadily from 2.6 per cent in 2010 to 3.3 per cent of Germany's total employment in 2017, for a total of 1.31 million ICT workers. Computer programming, consultancy and related activities employed the largest share of workers, followed by manufacturing of computer, electronic and optical products (see figure 1.1).

In Singapore, as of June 2018, there were 137,800 resident workers and foreign workers in the ICT service sector, with resident workers defined as Singapore nationals and non-Singapore nationals with permanent resident status.

This constituted 3.7 per cent of Singapore's total employment (Chua, 2018). In addition, there were 68,000 employed in the electronics industry in 2015, an industry in which a sizeable proportion falls under the umbrella of ICT manufacturing (SSG, 2017a).

▶ 1.4 Employment and working conditions in ICT occupations

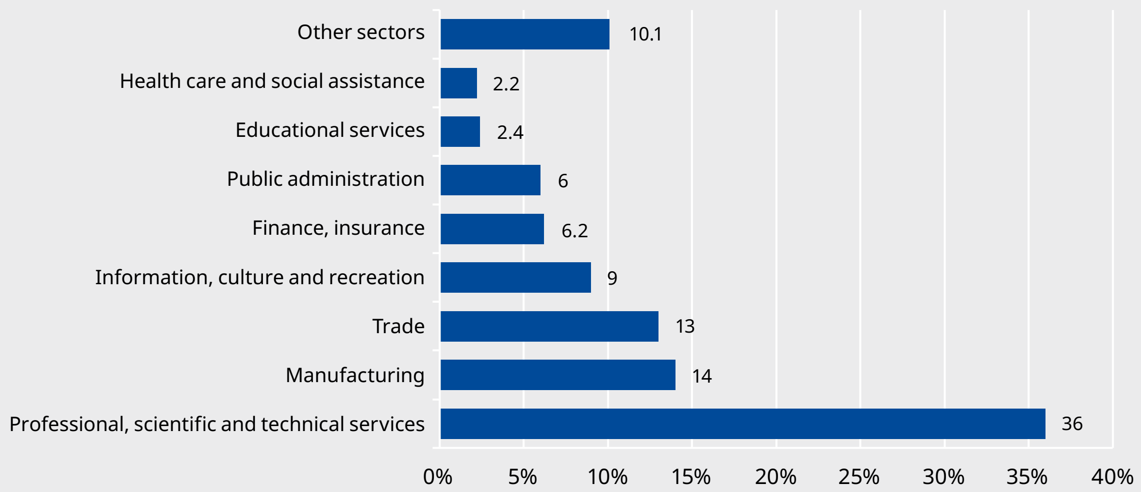
1.4.1 ICT specialists by sector

ICT specialists work in a variety of occupations, both within the ICT sector and in other sectors of the economy (see Annex Table A2 for occupational classifications). More than half of ICT specialists in Canada, Germany and Singapore are employed in sectors other than the ICT sector. The proportion of ICT specialists working in other, non-ICT sectors can be expected to increase in the future, as digitalization becomes more important in other sectors of the economy. Data on the employment of ICT specialists by sector are not available for China.

It should be noted that comparative analysis of employment in ICT occupations is challenging, as comparable, granular data are not available in all four countries. For instance, data on ICT specialists working in other economic sectors in China are not publicly available. Rapid technological advances and the emergence of new job roles make conducting such an analysis even more challenging.

8 ILO definition, see Annex Table A1.

▶ **Figure 1.2 ICT employment by industry – Canada, 2018 (per cent)**



Source: ICTC, 2019

Canada

According to ICTC, in 2018 there were approximately 1.3 million ICT specialists in Canada, accounting for almost 7 per cent of total employment (ICTC, 2018). Between 2014 and 2018, employment growth in the ICT sector outpaced overall employment growth in the Canadian economy. Statistics showed that most ICT specialists worked in the professional, scientific and technical services (36 per cent), manufacturing (14 per cent) and trade (13 per cent) sectors. According to ICTC, 59 per cent of ICT specialists work outside the ICT sector (ICTC, 2019c)

According to the wider definitions of ICT specialists used by the Employment and Social Development Canada (ESDC), the largest subgroups among those specialists were information systems analysts and consultants (15 per cent), computer programmers and interactive media developers (12 per cent), and technical sales specialists in wholesale trade (10 per cent) (see Annex Table A4) .

Box 1.1 describes another approach to identifying ICT specialists or “tech workers” in Canada that provides different insight into the numbers of ICT workers and the definition of their professions

Germany

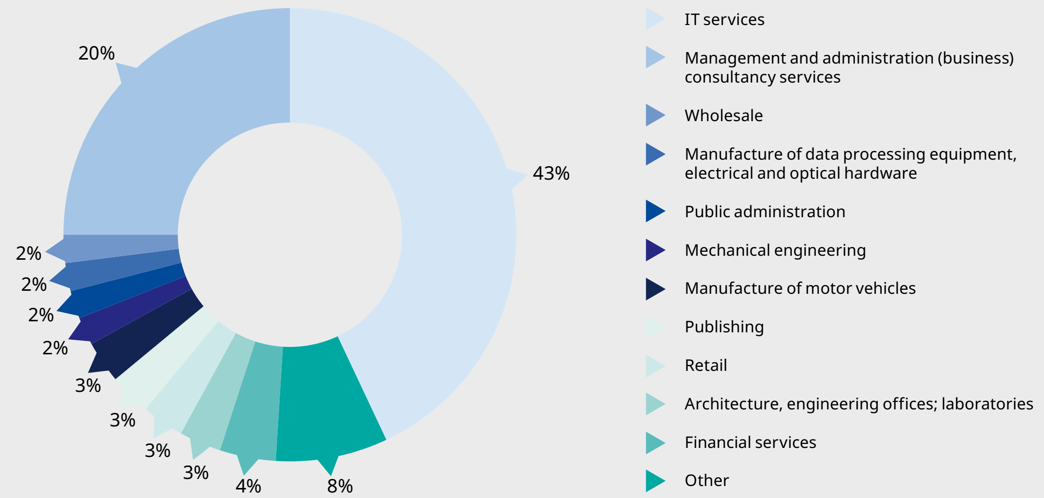
There are estimated to be 1.67 million ICT specialists in Germany, accounting for 4.7 per cent of total employment. The largest occupational subgroups among ICT occupations include electrical engineering, comprising

▶ **Box 1.1: Tech workers in Canada**

The Brookfield Institute has taken another approach to identifying ICT specialists. It links six digital skills described in the United States Bureau of Labor Statistics O*NET database to Canada’s National Occupational Classification. In 2016, the process identified about 935,000 individuals working in either digital occupations – with 73 per cent working in the development of computer hardware or software solutions, including as software developers or technology architects, and 27 per cent in high-tech occupations that required advanced technical skills in which computers were used as a part of other jobs, such as engineers or scientists. That number amounted to 5.1 per cent of the total Canadian work force. Therefore, between 2006 and 2016, the number of tech workers grew by 24 per cent, or 183,000 people.

Source: Brookfield Institute, 2019.

Figure 1.3 IT specialists subject to social insurance contributions by sector - Germany, 2018 (per cent)



Source: BA, 2019

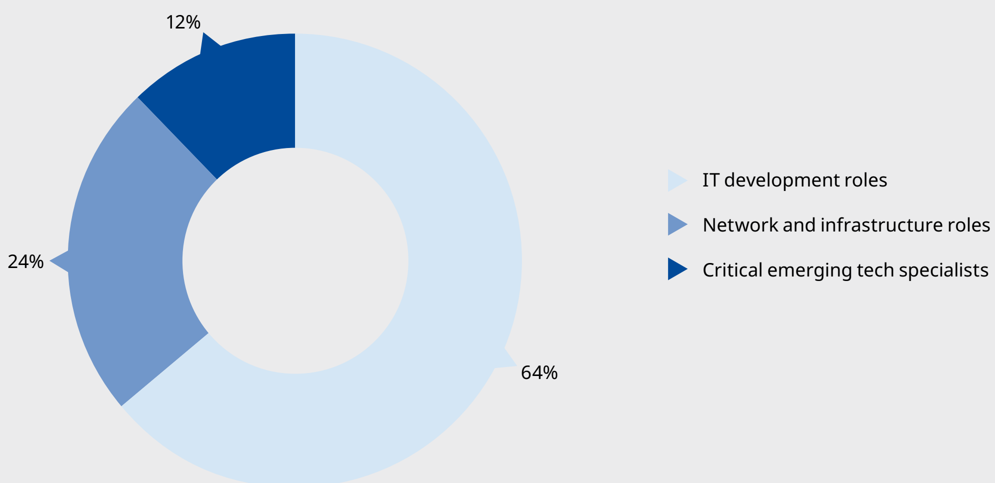
15.8 per cent of all ICT occupations, information and telecommunication technology at 12.6 per cent, software development at 12.2 per cent and computer science at 11.9 per cent (see Annex Table A6). The latter two groups (software development and computer science) are classified as "core ICT specialists" in Germany.

In 2018, about 43 per cent of core ICT specialists subject to social security were employed in the IT services sector and 8 per cent were employed in business administration and consultancy services. Together the manufacturing, mechanical engineering and the automotive industry sectors totalled about 9 per cent of ICT employees (see figure 1.3).

Singapore

In 2018, there were approximately 197,500 ICT specialists in Singapore, comprising 5 per cent of total

Figure 1.4 Roles of employed ICT specialists - Singapore, 2018



Source: IMDA, 2019

employment (see Annex, Table A10 for the definition of ICT specialists in Singapore). In Singapore, more ICT specialists work in non-ICT sectors than in the ICT sector itself (Research mission interview, IMDA, 2019). About 88,000 ICT specialists are professionals employed in IT-development roles, followed by professionals employed in network and infrastructure roles at 32,100, with 16,400 working as critical emerging tech specialists (IMDA, 2019). Critical emerging tech specialists include data analysts/data scientists, machine learning/AI engineers, IT security specialists, IT security operations analysts/engineers, Infocomm R&D, IoT engineers, embedded systems/firmware developers, and IoT solution architects.

1.4.2 The role of start-ups

Start-ups can have a significant impact on the economy and society and may also drive innovation. In general, they have been shown to have a positive effect on job creation (ITU, 2016). There are an increasing number of start-ups in ICT in Canada, China, Germany and Singapore. The Governments in all four countries have introduced policies to foster an environment conducive to start-ups.

Canada

In Canada, the Innovation, Science and Economic Development Canada (ISED) is establishing programmes and funding opportunities to support innovation initiatives and start-ups, including a strategic innovation fund oriented towards early stage research and accelerated programmes that provide hands-on support through innovation advisors. Those programmes are intended to help companies scale up from start-ups to become full-scale business enterprises (Research mission interview with ISED, Canada).

China

The Government of China is successfully promoting the establishment of start-up companies in the ICT sector, with the result being that one third of private start-up companies valued at over US$1 billion, and commonly known as “unicorns”, are located in China (Shi-Kupfer and Ohlberg, 2019). One example of China’s ICT-related start-up policies is the Garage Café, a platform and physical space to provide entrepreneurs with resources and experience, including amenities such as free office space. The company was founded in Beijing in 2011 with the support of local government. Individuals interested in becoming entrepreneurs can come together to exchange information and present their ideas in order to receive feedback and comments that can help them bring their ideas to fruition. One factor facilitating the dynamic start-up scene in economically vibrant parts of China is that individuals with failed start-ups are not penalized by the labour market when looking for employment elsewhere, and some entrepreneurs continue to set up start-ups over and over again (Research mission interview with Garage café, China).

Germany

The ICT sector has attracted a large share of start-ups in Germany. According to a 2019 survey of start-ups that began in 1988, about 30 per cent of start-ups were established in the ICT sector (Kollman and others, 2019). The federal Government runs several programmes to support the start-up scene. Primary programmes include the EXIST programme, with 2017 funding of 61.2 million euro (€), equivalent to approximately US$72.0 million, for technology-oriented and knowledge-based start-ups, the *ERP-Gründerkredit – StartGeld* [Founder Credit – Start Money], which provides loan capital of up to €100,000 (US$117,892) for business founders and small companies started less than five years ago, and the High-Tech Gründerfunds [High Tech Founder Funds], a fund for highly innovative, technology-oriented companies that began operating less than three years ago. The federal Government states that federal venture capital funding tripled between 2005 and 2017, to €1.049 million (US$1.24 billion) in 2017 (Bundestag, 2018a).[9]

Singapore

The government has put infrastructure in place to help start-ups with funding, access to technical expertise, skills development, and other support. For instance, the Scale-up SG programme and Innovation Agents Programme are aimed at helping start-ups scale up and venture into new markets.

As of June 2019, there were 4,713 Singapore start-ups registered on Asia’s largest tech media platform, e27 - where e stands for entrepreneurs and 27 is the median age of entrepreneurs. Of these, 1,085 are part of the ICT sector, comprising 23 per cent of the start-up population.

9 Exchange rate calculated on 7 August 2020.

1.4.3 Educational level of ICT specialists

On average, ICT specialists have a higher level of formal education when compared to the general employed population.

The desk review and the research interviews highlighted that work experience and certifications, such as those offered by large tech brands, can be more important than formal qualifications, depending on the job role and individual cases. This may be a result of rapid technological changes and an increase in demand for ICT specialists that is not being matched by an increase in supply of ICT specialists. This has led to more self- taught specialists who have acquired their skills through informal and non-formal learning.

Canada

In 2017, an estimated 30.5 per cent of the total Canadian workforce had a university degree. The figure is much higher for ICT specialists, 55 per cent of whom held a university degree. That figure continues to increase. Table 1.2 shows the breakdown of employees with a university degree within the ICT sector (ISED 2019).

About 62 per cent of ICT managers held university degrees in 2017, up from 53 per cent in 2007. ICT technicians are usually required to have a college-level education, defined as a form of post-secondary education where students can obtain a diploma, certificate and, in some cases, a bachelor's degree in two to three years (Research mission interview with ISED).

▶ **Table 1.2 Percentage of employees with university degrees in the ICT sector by job area, 2017**

Area within ICT sector	Percentage of employees with university degrees
Software and computer services	62.2
ICT wholesaling	49.3
ICT manufacturing	38.5
Communications services	34.2
Total ICT Sector	**55.0**
National average	**30.5**

Source: Government of Canada.[10]

China

In China, a 2017 survey of approximately 600 companies in the semiconductor industry indicated that their workers have high skills levels.[11] The majority of individuals employed in the semiconductor industry held a bachelor's or master's degree and most ICT specialists working at integrated circuit design, electronic design automation (EDA) and intellectual property (IP) enterprises had a master's degree. In foundry, IDM and semiconductor testing and packaging enterprises, the proportion of university graduates was also found to be high. Furthermore, the high proportion of workers employed in R&D in the industry also reflects high skills levels (Country report prepared for China).

Germany

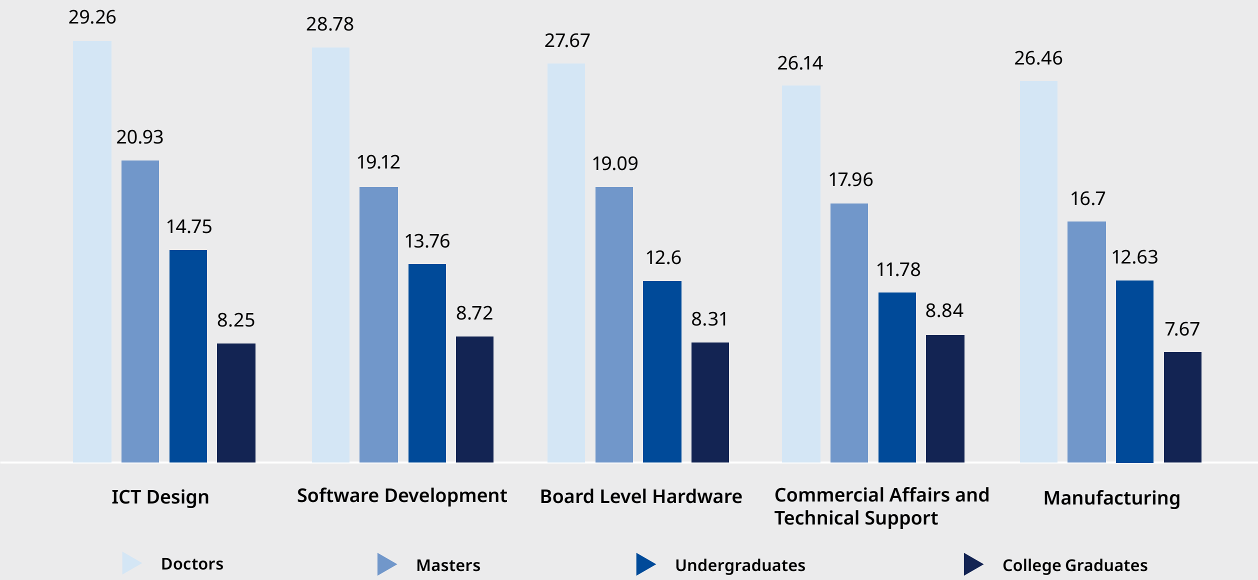
Among employed ICT specialists, the proportion of those with a university education (36.6 per cent) is much higher than the average rate across all occupations in the labour market (18 per cent), while the share of workers with vocational training is much lower (52.3 per cent, compared to 68.7 per cent across all occupations).[12] Data on skills levels required to perform jobs within ICT indicate that 25.9 per cent need to perform "highly complex tasks" requiring a master's degree or above, 35.7 per cent need to perform "complex tasks" requiring a bachelor's degree or equivalent degree from the Vocational Education and Training (VET) system[13] and 30.8 per cent need to perform "skilled tasks" that usually requires a three-year VET degree.[14] Job profiles for core ICT occupations, a software developer for example, require a higher skills profile, given that 73.5 per cent need to carry out "highly complex tasks" (see Annex Table A7).

Singapore

In Singapore, ICT specialists and information, communication and media (ICM)[15] specialists are highly educated at significantly greater rates than the Singaporean workforce at large. As of 2018, 11.5 per cent of ICM professionals had up to A Level[16] qualifications, while 16.9 per cent held diplomas, 58.8 per cent had a bachelor's degree or post-graduate diploma,

10 For further information, see: www.ic.gc.ca/eic/site/ict-tic.nsf/eng/h_it07229.html.
11 Data are not available for other industries within the ICT sector.
12 Data refer to employed ICT specialists subject to social security. BA administrative data; author compilation, 2019.
13 Individuals with an initial VET degree and an additional degree in continuing vocational training within the formal VET system, including a Meister-degree for technical/vocational school graduates.
14 In Germany a distinction is made between skills and formal education requirement levels. Occupations are grouped into four levels: (A) *Helfer* [helper]: persons without a formal vocational qualification or those that graduated with a one year VET course; (B) *Fachkräfte* [skilled workers]: people with formal qualifications according to the VET system with an education and training scheme of at least 2 years; (C) *Spezialisten* [specialists]: persons with an initial formal VET degree and an additional degree in vocational continuing training within the formal VET system, a master's degree for example, and/or those who graduated from a technical/vocational school or from university with a bachelor's degree but who lack work experience, and; (D) *Experten* [experts]: people with at least a master's degree or equivalent, or graduates from a tertiary study scheme lasting a minimum of four years.
15 Data in Singapore about ICT specialists is always presented in terms of those working in the media sector.
16 A Level is the common name for the General Certificate of Education Advanced Level Certificate (GCE A Level), typically taken by students in Singapore at age 18, prior to university entry.

▶ **Figure 1.5 Average salary of graduates in different integrated circuit industry positions China, 2017 (10,000 Yuan Renminbi = US$1,435)**



Source: Country report prepared for China

11.7 per cent had a master's degree and 1.1 per cent had a doctorate. The proportion of the total workforce holding a university degree in 2019 was 37.5 per cent (IMDA, 2019).

1.4.4 Wages for ICT specialists

In all four countries, wages for ICT specialists are on average higher than for other occupations with comparable levels of formal qualifications, due to the shortages of supply and fierce competition to attract skilled workers.

Canada

In Canada, on average, employees in the ICT sector earn more than 77,800 Canadian dollars (CAD) or the equivalent of US$58,142 per year. In 2018, those workers earned 49.4 per cent more than the economy-wide average. The highest earners were working in the wholesaling and software and computer services subsectors and earned on average CAD88,171 (US$65, 899) and CAD83,381 (US$62,319) respectively. The lowest paid employees in the sector worked in ICT manufacturing and communication services and earned on average CAD66,183 (US$49,465) and CAD62,134 (US$46,436). Even the lowest paid ICT sector employees still earned 27 per cent more than the national average wage (Government of Canada, 2019).[17]

According to another study, conducted in 2016, that looked at job roles and wages, tech workers, and high-tech workers in particular, were paid considerably more than non-tech workers[18] (Brookfield Institute, 2019). The wage differences were explained by two factors: the higher proportion of university graduates and the high demand for ICT specialists.

China

Wage levels in the ICT sector are much higher than in other industries (Research mission interview with ACFTU, China). Wages in the ICT sector doubled between 2012 and 2016, while in the workforce in general, wages grew by 50 per cent on average (Zhan and Chen, 2019). Survey data on the semiconductor industry showed that there is a significant pay-off for having a high-level university degree (see figure 1.5).

17 Exchange rate calculated on 7 August 2020.
18 This study uses another analysis method to identify ICT specialists and calls them tech workers. Comparisons of these statistics and others from ICTC and the Government of Canada must be undertaken carefully. For an understanding of what constitutes a tech worker, see Brookfield Institute, 2018.

Germany

In Germany, the median income for graduates working full-time ten years after graduation, based on a graduation year of 2005, is €67,900 (US$80,033) for university graduates in engineering/computer science/mathematics, compared to a median income of €52,800 (US$62,235) for graduates from all university fields of study (Autorengruppe Bildungsberichterstattung, 2018).[19] However, according to a survey conducted by an ICT industry association, nearly three quarters of employers indicated that applicants' wage expectations were too high, and half indicated that wage expectations did not match skills levels (Bitkom, 2019b).

Singapore

In Singapore, according to the Ministry of Manpower (MOM), median annual gross wages for ICT roles range from 52,000 to 66,000 Singaporean dollars (SGD) or between US$37,885 and US$48,085. This compares favourably with the national median wage, which is SGD39,600, or US$28,851 (MOM, 2018).

New university graduates who have completed information and digital technologies courses were earning a gross monthly median salary of SGD4,022 (US$2,930) in 2018. New polytechnic graduates from information and digital technologies courses were earning a gross monthly median salary of SGD2,450 (US$1,785) in 2019, which has increased since the 2018 and 2017 median incomes of SGD 2,390 (US$1,741) and SGD2,300 (US$1,676) respectively.[20] The wages of both types of graduates have increased by 6.5 per cent over the past two years. Both university and polytechnic graduates from information and digital technologies courses earn gross monthly median salaries that are among the highest paid to their cohorts.

1.4.5 Working hours

The desk review and interviews indicate that ICT specialists tend to have long working hours and interviews conducted in Canada and China supported this finding. In Germany, statistics show that ICT specialists worked longer hours than the economy-wide average. However, the share of ICT specialists working longer hours was quite low in Singapore.

While labour laws often prohibit long working hours over a protracted period, enforcement varies (BMWi, 2018b). In some cases, ICT specialists may be exempt from working hour laws. Long working hours may lead to higher staff turnover (Research mission interviews).

Canada

Working hours for most employees in Canada are regulated provincially, including those of ICT specialists (Legault, 2013). This means that working time regulations for ICT specialists differ by province, and in some cases, ICT specialists may be exempt from working time regulations. For example, in British Columbia, IT professionals are excluded from provisions dictating hours of work, overtime and statutory holiday as per the Employment Standards Act. This issue came to light when ICT workers made a submission to the Ontario Changing Workplaces Review (Fairey, 2017).

China

In China, a common work schedule in the ICT industry is known as the "996 phenomenon" – that is, working from 9 a.m. to 9 p.m. from Monday to Saturday, which is unique among Chinese industries (Research mission interview with CEC/CEDA, China). However, this type of work schedule might not be common in government owned companies and small cities. In speaking with individual employers about this, they tended to point out that this type of schedule is linked to the nature of the work, which involves developing and searching for solutions. Since this requires a creative working process, it can often lead to intensive work periods (Research mission interviews with several private companies, China).

Germany

In Germany, working time is regulated by law, which sets the maximum daily working time. Daily hours are usually eight hours with maximums set at ten hours, and weekly working hours are limited to a maximum of 48 hours. Minimum rest times of 11 hours and compensation time for periods in which workers are needed to work for longer hours are also stipulated by law.

In 2019, the average amount of paid overtime per employee in the ICT sector was 24.8 hours per month, which was slightly higher than the average for all industries, where paid overtime per employee was 23.6 hours per month. In addition, employees in the ICT sector performed 35.1 hours of unpaid overtime a year. This was significantly higher than the

19 Exchange rate calculated on 7 August 2020.
20 Exchange rate calculated on 7 August 2020.

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annual average of all sectors overall, where unpaid overtime was 23.3 hours per year per employee. It can be assumed that overtime is linked to the rising demand for ICT specialists and the consequent labour shortages.[21]

Singapore

In Singapore, a country where long working hours are widespread across industries, the proportion of workers who worked more than 48 hours a week in the ICT sector was 17.9 per cent. While this is lower than the national average of 20.9 per cent, it indicates that a visible percentage of ICT specialists work long hours (MOM, Labour Force Survey, 2018).

1.4.6 Occupational safety and health

In general, ICT specialists are faced with lower occupational safety and health risks than other occupations. While physical risks are limited, those working with digital tools cite musculoskeletal disorders and eye strain. Additionally, psychological risks such as stress related to office work can cause physiological symptoms including headaches, nervousness and irritability.

New human resource management principles, including results-based management, allow workers to organize their working time and telework flexibly, although these may also lead to work intensification and overtime that is not declared. Occupational safety and health conditions can also be more difficult to monitor and control in teleworking arrangements.

The COVID-19 pandemic has helped to reveal significant untapped potential for telework, as teleworking has increased substantially curing the crisis. In the European Union (EU), about 37 per cent of workers have been teleworking since the lockdown. The percentage of workers teleworking in Germany is similar to the EU average (Eurofound, 2020a). Teleworking particularly increased among those occupation groups that were already teleworking more often. Statistics Canada estimates that around 39 per cent of jobs in Canada can be performed remotely. It is, moreover, estimated, that 84 per cent of professional, scientific and technical services in Canada can potentially be performed from home.

During the COVID-19 pandemic and the accompanying lockdown measures, working during free time was reported by 18 per cent of teleworkers in the EU (Eurofound, 2020b). Some of these workers had to work additional hours to meet labour demand, while others had to fully rearrange their working schedules in order to manage caring for children, teleschooling and telework. The exceptional circumstances of the pandemic have resulted in a stressful situation for many workers (Eurofound, 2020b; Hans-Böckler Stiftung, 2020). Previous surveys indicate that, in general, workers with telework and ICT-based mobile working arrangements are more likely to report working long hours and not having enough rest between working days. Stress factors include permanent connectivity and increased job intensity (Eurofound, 2020a).

Studies have shown that those working in IT can be prone to high stress levels as the industry often demands high quality work in a short period of time. Workers in this industry are therefore at risk for burnout (Nagaraj and Mahadevan, 2015). In Germany, a survey of 9,600 employees conducted by the German Trade Union Confederation (DGB), showed that employees who work very extensively with digital work tools feel stressed and under time pressure more often than workers who do not work with digital work tools (Institut DGB, 2017). On the other hand, working as an ICT-specialist is usually an occupational choice and, given the use of digital tools and flexibility for telework, could be an employment option for persons with disabilities. An example of a policy for promoting inclusive jobs was a project in Germany that provided three and a half years of government financial support for VET in ICT occupations for persons with disabilities.[22]

The German United Services Trade Union (ver.di), analysed data on work intensity from the 2019 survey conducted by DGB to inform its quality of work index. Survey results show that among IT and natural science service workers, 35 per cent stated that the tasks they were given were often or very often not doable within the given time frame. This was higher than for other service sector occupations.[23]

According to a government-led survey on mental health in China in 2018, half of the 400 tech workers surveyed said they were fatigued. Only a few tech companies in China provide mental health counselling services.[24] According to another survey conducted

21 For further information see: www.tecchannel.de/a/it-projekte-machen-krank,2077172; www.golem.de/news/it-fachkraeftemangel-arbeit-ohne-ende-1907-142513.html; www.marketing-boerse.de/fachartikel/details/2011-burnout--ueberstunden-it-security-abteilungen-am-limit/165231

22 For further information see: www.inklusive-it-berufe.de/das-projekt/ and www.talentplus.de/in-beschaeftigung/was-ist-behinderung/feststellung-der-behinderung/index.html?infobox=/infobox1.html&serviceCounter=1&wsdb=FOR&connectdb=forschung_detail&referenznr=R/FO125462&from=1&anzahl=134&detailCounter=23&suche=index.html?suchbegriffe=%22Jugendlicher%22&intlink=true

23 For further information see www.innovation-gute-arbeit.verdi.de/++file++5de8b20f73b0ebd8df74f05b/download/DGB-Index%20Gute%20Arbeit%20-%202019_Der_Report_Arbeitsintensit%C3%A4t.pdf

24 For further information in Chinese, see: www.zhuanlan.zhihu.com/p/57750355.

by All-China Federation of Trade Unions (ACFTU) regarding concerns among ICT workers, many ICT workers identified mental health problems caused by high pressure situations and long working hours as challenges. Helping employees cope with these challenges is now an important issue for trade unions.

An example of an ICT company that has taken the initiative to address mental health issues in the workplace is the telecommunication company Bell Canada, which runs a mental health programme in which all managers are trained on appropriate ways to discuss mental health issues with their workers. Managers also receive training about the types of support that should be provided (Research mission interview with Bell Canada).

1.4.7 Self-employment and platform work

In Canada and Germany, the self-employment rate among ICT specialists was around 12 per cent (Statistics Canada and Labour Force Survey Germany, 2016).[25] It was much lower in Singapore, at around 5.5 per cent. There are no data available for China on ICT self-employment.

Companies use self-employment, freelance and temporary agency work for various reasons, including:

- **a** To meet a need for specific ICT skills for project implementation, such as through temporary consultancy work;
- **b** To address labour shortages for very specific skills or recruitment difficulties in specific sectors;
- **c** Because companies prefer to engage older ICT specialists as consultants or independent experts rather than as full-time hires (See section 1.7).

Furthermore, some companies in Germany are actively bringing older workers back from retirement by employing them as freelancers on a part-time basis (Research mission interview with Modis, Germany).

Online platform work is a specific form of self-employment prevalent among those in ICT occupations. Software developers represented 38 per cent, and thus the largest occupational group, of online platform workers in Canada and in Germany (Kässi and Lehdonvirta, 2016).

Findings from several sectors across the economy show that platform work can be a way to supplement income, combine care responsibilities with work, allow workers to set their own schedule and provide income earning opportunities for people with health conditions. On the other hand, platform workers tend to be underpaid, lack access to social security and often perform tasks that do not match their skills level. Another potential risk related to this form of work is that it might affect workers' skills development, since it shifts the responsibility for investing in skills development from the company to the individual (ILO, 2018).

There are discussions taking place about how governments should reform social protection systems to ensure coverage for platform workers. A group of experts at the European Commission suggests creating a digital single window for employment contributions and taxes for the self-employed who are working on online platforms for multiple employers on a changing basis (European Commission, 2019).

In Singapore, there are estimated to be around 7,000 ICT gig workers. The Tech Talent AssemBly (TTAB) perceives gig platforms to be advantageous as they can serve as a bridge to the labour market – particularly for mid-career and older workers, as older workers have a low probability of finding employment again once they are unemployed. This is because opportunities on gig platforms can both provide experience and serve as proof of experience to potential employers (Research mission interview with TTAB, Singapore).

In Germany, the metal industry trade union IG Metall has established a new platform to provide an online counselling service, including on legal issues, for crowdworkers[26] (Informationstechnologie & Telekommunikation (ITK), 2015). Crowdworkers do not have to be members of the trade union to access the services provided (Research mission interview with IG-Metall, Germany).

A similar initiative has been proposed in China, where a group that has been organizing ICT workers within ACFTU has proposed the formulation of a framework for online counselling services for ICT workers, which could be particularly beneficial for mid-career and older workers (Research mission interview with ACFTU, China).

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25 Data for Germany refer to the computer programming and consultancy sectors and information service activities.
26 Crowdworkers are those that obtain work on web-based platforms, where work is outsourced through an open call to a geographically dispersed crowd.

▶ 1.5 Recruitment difficulties and strategies to retain workers

1.5.1 Recruitment

In all four countries, companies report difficulties recruiting ICT specialists, particularly software developers and specialists in new digital technologies, or specialists with interdisciplinary skills in industries such as health or finance where the role of ICT workers is increasing. SMEs encounter more difficulties when hiring ICT specialists, because they are perceived as less attractive prospective employers by ICT specialists, particularly because they are not as well-known and because they often find it challenging to match the higher wages paid by large companies.

While strategies used to recruit skilled workers do not differ greatly between the four countries, they are more likely to differ by job role and industry. A common feature is that companies are becoming more proactive in their search strategies and are leveraging social networks rather than traditional channels. They are also offering incentives for employees if they help recruit ICT specialists through their own networks. For example, iDreamsky, a Chinese gaming company with 800 employees, recruits around 60 per cent of its employees through internal employee referral channels.

Although many companies would prefer to hire young workers that already have some work experience, they are also having to hire many recent graduates, as the market for experienced ICT workers has become highly competitive (Research mission interview with the semiconductor company Infineon, Germany). When recruiting talent, the trend is towards hiring those with potential rather than hiring proven skills.

Recruitment agencies also provide training to ICT candidates who have potential – including older workers or those who have changed careers – to match the skills demand of companies. For instance, the recruitment agency Academic Work runs the AW Academy in Germany, which offer 12-week accelerated training courses. In Germany, Modis has established an online training framework for candidates who wish to improve their skills and/or obtain certificates. After completing training, workers are either placed with agencies as temporary workers or hired by companies. Payment modalities for training varies. In the case of AW Academy, training is paid by Academic Work, and therefore the pre-selection of candidates is highly competitive (Research mission interviews with Academic Work and Modis, Germany).

1.5.2 Retention

Staff turnover is generally high in both large and small ICT companies, as such workers tend to be relatively mobile and will often seek interesting projects and better paid opportunities.[27] Given the high costs associated with recruitment and difficulties in finding talent, some companies are developing targeted strategies to retain workers. In addition to, or as an alternative to, competitive salaries, companies aim to retain workers by providing access to training opportunities for skills development and by creating an attractive work culture.

One example of this type of strategy is the approach adopted by Singapore-based cyber security company, Ensign Infosecurity, which offers numerous amenities, including a gym and bar, and also provides employees with the opportunity to take three to four-week sabbaticals. A Canadian SME, Semios, identified that giving employees time during the work week where they can get together and talk about their current work helps to attract and retain young ICT specialists (Research mission interview with Semios, Canada). Other companies offer continuous training opportunities in order to be seen as attractive employers to potential recruits.

▶ 1.6 Employment and career opportunities for women

1.6.1 Female employment in ICT

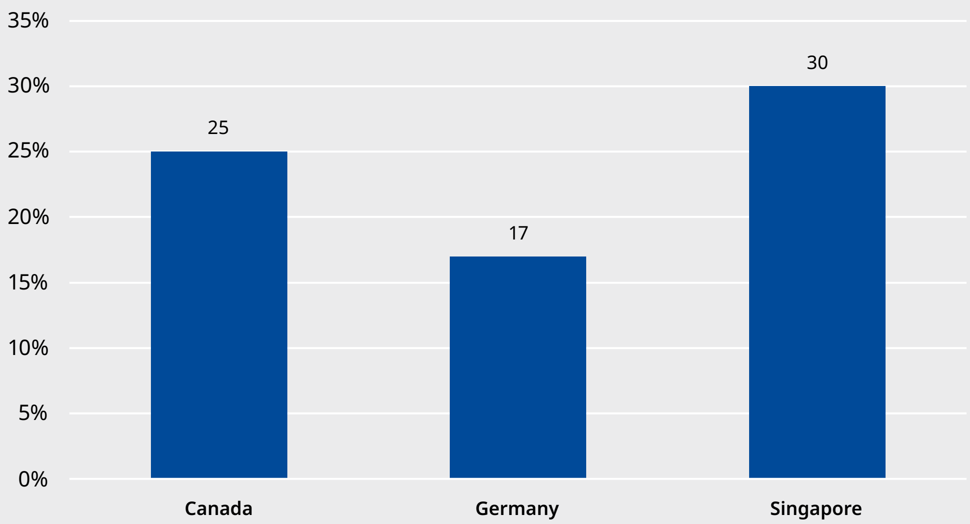
In all four countries the proportion of women among ICT specialists is well below economy-wide averages in the overall workforce (see figure 1.6).

In Canada, women comprised approximately 25 per cent of ICT specialists in 2018. This is higher than in Germany, where only 17.1 per cent of ICT specialists were women in the same year (German Federal Ministry for Labour and Social Affairs; author calculation).

27 For further information see: www.business.linkedin.com/talent-solutions/blog/trends-and-research/2018/the-3-industries-with-the-highest-turnover-rates

contents

▶ **Figure 1.6 Female ICT specialists as a proportion of all ICT specialists (per cent)**



Source: Annual Survey on Infocomm Media Manpower, Singapore, 2019; BA data on dependent employees; author compilation; ICTC, Canada.

In Singapore, women are significantly under-represented, and comprised only 30 per cent of all ICT and media employees in 2018, as compared to 45 per cent in the overall workforce (IMDA, 2019). In addition, the proportion of women in ICT can be assumed to be even lower if media roles are excluded. For example, among employees at the ICT consultancy and recruitment agency Xcellink, the proportion of women was 20 per cent, while at Ensign Infosecurity it was 10 per cent (Research mission interviews, Singapore).

Data on the proportion of women working as ICT specialists in China are not publicly available and it is therefore not possible to make a concrete assessment of the levels of female employment in the ICT sector. However, company interviews conducted in China indicated that the proportion of women employed as ICT specialists is significantly below the labour market average. On a positive note, interviewees also observed that the proportion of women in the field was slowly increasing (Research mission interviews, China).

Delving deeper, the proportion of women in ICT varies largely by occupational subgroup. Occupations in software development and programming tend to have the lowest numbers of women employees, while occupations where ICT is applied to media, health and business administration or job roles that have graphic and arts components tend to employ a much larger proportion of women. For example, nearly 50 per cent of graphic designers and illustrators in both Germany and Canada were women, and 89 per cent of health information management managers in Canada were women (Statistics Canada and BA, 2019).

1.6.2 Gender wage gap

The gender wage gap can be explained by, among other things, stereotypes and the discrimination resulting therefrom that impact women's opportunities in education. As a consequence, this negatively impacts their chances of taking advantage of employment opportunities and receiving equal treatment in labour markets. In ICT jobs in Canada, men earned 10.5 per cent higher wages than women did. That was less than the national average differential, however, which was 25.6 per cent. Analysis suggests that the wage gap increases as differences in education increase (Brookfield Institute, 2019). In Germany, wage differences between men and women in ICT were below economy-wide averages, but were nonetheless significant. For example, male IT consultants earned 7.8 per cent more than women, and male IT project leaders earned 18 per cent more (Gehalt.de, 2018).

Given that gender wage gaps are largely influenced by occupational segregation, the difference in remuneration is significant and indicates unequal career progression opportunities. For example, in Singapore, men earned 9.2 per cent more than women in software and web development occupations and 9.8 per cent more in the field of electrical engineering, while

Box 1.2: Enhancing employment in ICT occupations with a view to addressing the gender pay gap

Women account for only 17 per cent of the 8 million ICT specialists working in Europe. The ICT sector is one of the highest paying sectors in the EU and the demand for STEM jobs is expected to increase by 8 per cent between 2013 and 2025. Increasing the participation of women in ICT jobs therefore presents a significant opportunity for the EU and can also contribute to reducing the gender pay gap. The European Institute of Gender Equality states that attracting more women to the STEM sector, "would lead to economic growth, with more jobs (up to 1.2 million by 2050) and increased GDP over the long-term (up to €820 billion (US$967 billion) by 2050)".

However, to harness the potential of the sector's growth for women's employment, several policy measures need to be implemented to address biases. For example, Bulgaria has the highest proportion of women in technology in the EU, at 35 per cent. This is due to a combination of governmental policies and local initiatives led by women in technology. Non-governmental organizations (NGOs) aiming to reduce gender disparities in ICT and STEM can also play a big role. As a result of activities by stakeholders including the Competence Center Technology-Diversity-Equal Opportunities e. V., a non-profit association that works to promote equal opportunities in work, training, education, science, and research, the share of women in ICT jobs in Germany is increasing more substantially than in other countries.

These cases suggest that public policies, appropriately combined with bottom-up initiatives and the involvement of local associations, could successfully address gender based discrimination in the ICT sector.

For further information see: https://www.europeandatajournalism.eu/News/Data-news/The-ICT-sector-is-booming.-But-are-women-missing-out; https://eige.europa.eu/publications/work-life-balance/eu-policies-on-work-life-balance/women-in-ict

women earned more than men as account and financial analysts (MOM, n.d.) [28].

Evidence suggests that promoting the employment of women in ICT occupations can help decrease the gender wage gap across the economy and contribute to economic growth overall (see box 1.2).

1.6.3 Obstacles to career development

According to a survey of 500 ICT companies conducted in Germany by Bitkom, the Federal Association for Information Technology, Telecommunications and New Media, over half of all companies and 80 per cent of large companies state that they have set themselves the objective of hiring more women. However, in Germany, women currently comprise only 15 per cent of candidates applying for jobs as ICT specialists in the ICT sector, according to that survey.

The Brookfield Institute released the results of a survey on the Toronto tech industry by the technology incubator MaRS, in which women and men in the tech sector were asked about their sense of belonging (Brookfield Institute, 2019). The results showed that women in tech occupations felt less comfortable voicing their opinions and being authentic at work than men did, and their sense of belonging was also not as strong as men's. Furthermore, women did not feel as encouraged or supported to be innovative at work as men did. When asked about inclusion, women responded that tasks were not being divided as fairly as men thought they were, and they did not feel as much a part of decision-making processes at work as men. Lastly, women perceived a lack of fairness around salary and benefits much more strongly than men did. Those results were echoed by the outcome of a recent women in technology survey of employees conducted by ICTC. That survey indicated that a significant proportion of women felt that their voices were not heard. When asked, women felt that coaching or mentoring, equal pay and flexible work policies would enhance their workplace experience.

The aforementioned Bitkom survey demonstrates that the main factors hindering women's career development include a lack of childcare facilities, long working hours and a lack of flexibility in workflow organization. One quarter of human resource management indicate that the low proportion of women in managerial positions in the ICT sector is linked to the perception that the sector is not attractive; with more than one fifth relating it to the prevalence of gender stereotypes (Bitkom, 2019a).

Data collected suggest persistent gender discrimination in the career progression of ICT specialists. In Canada and Germany, although women are

28 Note that the analysis does not take into account differences in years of education and experience.

Box 1.3: Programmes to promote gender diversity in the workplace in Singapore

IMDA supports several initiatives that aim to increase gender diversity in the workplaces for ICT specialists. These include:

- Mentor Connect: IMDA, Dell Technologies and ST Engineering have launched a cross-company mentorship programme that provides mentoring, leadership and networking opportunities for professionals, with a focus on women mentees in its first iteration.
- SG Women in Tech Community Platform: A joint initiative between IMDA and SGInnovate. This is an online platform that aims to provide a supportive community for women tech professionals to share resources in infocomm media technologies.

In addition, trade associations such as the Singapore Computer Society also support diversity in tech. The Society has established a Women in Technology Special Interest Group (WiT@SG), with the aim of increasing female participation in the technology sector through the creation of a platform for professional women to connect, learn and lead in the industry. WiT@SG builds an active community by running networking events and provides thought leadership intended to connect to a new generation of talent and encourage the entry of women into the industry.

For further information, see: www.imda.gov.sg/news-and-events/impact-news/2019/11/Empowering-women-in-tech and www.scs.org.sg/mobile/SIG/sig-wit.php

under-represented at all levels, the proportion of women in managerial positions is especially low (Brookfield institute, 2019; Bitkom, 2019a). In addition, sexual harassment of female ICT specialists is also an issue in certain workplaces, with certain cases having received press coverage.

In Singapore, the proportion of women serving as board members has recently increased across all industries, including the ICT sector (Diversity Action Committee Singapore, 2019). Furthermore, there are several initiatives to increase gender diversity in the workplace (See Box 1.3).

1.7 Employment and career opportunities for mid-career and older workers

Overall, ICT specialists tend to be younger than workforce averages; this is particularly true for those in new digital technology job roles.

In 2016, the median age for all workers in Canada was 42.6 years of age. Almost all ICT occupations, excluding managerial positions, had a lower median age than the national average. However, the proportion of ICT workers who are middle aged or older is increasing. From 2006 to 2016, those 45 to 64 years of age saw the largest growth in the number of tech workers, at 129,000 workers (Brookfield Institute, 2019). In Germany, 15.2 per cent of workers in the ICT sector were 55 years of age and older in 2018, significantly below the national average of 20.1 per cent for that same age group (United Nations Department of Economic and Social Affairs, Statistics Division, 2008). In Singapore, ICT workers were much younger than in Germany: workers 50 years of age and older constituted only 10 per cent of ICT specialists in Singapore in 2015, compared to a 34 per cent share of the total workforce. Approximately 44 per cent of ICT specialists were 30 to 39 years of age (IMDA, 2016; MOM, 2019).

Data from Germany suggest that older ICT specialists face a higher unemployment risk than younger ICT specialists.[29] This may be one of the reasons why older workers are more likely to be self-employed or consultants employed via temporary work agencies. Employers' assessments of the strengths and weaknesses of older workers are mixed. Perceived strengths include their knowledge of older programming languages, which are still relevant in some sectors, including banking and the public sector (Research mission interviews in Germany, Canada and Singapore). Perceived weaknesses include an assumed lower technical proficiency level and greater concerns about fitting into company culture, as indicated by the results of a survey of respondents across 220

29 The unemployment rate of core ICT specialists is 4 per cent among older ICT specialists, as compared to 2.1 per cent among younger ICT specialists (BA, 2019a).

companies in Singapore (SGTech, 2019). Companies also viewed older workers not only as less adaptable but also as more expensive (Research mission interview with Modis, Canada).

1.8 The role of ILO constituents

Constructive social dialogue among tripartite constituents – governments, employers' and workers' organizations – can play a crucial role in addressing key economic and social issues, including the challenges and opportunities faced in the ICT sector. Social dialogue is covered under the ILO Tripartite Consultation (International Labour Standards) Convention, 1976 (No. 144). Constructive social dialogue includes all forms of negotiation, consultation and information exchange, collective bargaining and dispute prevention and resolution. Social dialogue "comes in various forms and levels according to national traditions and contexts, including in the form of cross-border social dialogue in an increasingly complex globalized economy. There is no one-size-fits-all approach to organize and strengthen social dialogue. However, collective bargaining remains at the heart of social dialogue. Consultations, exchanges of information and other forms of dialogue between social partners and with governments are also important."[30]

According to the ILO Declaration on Fundamental Principles and Rights at Work and its Follow-up, all Member States have the obligation to respect, promote and realize the right to freedom of association and the effective recognition of the right to collective bargaining. ILO conventions covering these rights are the Freedom of Association and Protection of the Right to Organise Convention, 1948 (No. 87) and the Right to Organise and Collective Bargaining Convention, 1949 (No. 98). These conventions are critical components to a well-functioning labour market and the digital economy.

1.8.1 Governments

The role of government is a key to addressing skills shortages and promoting better governed labour migration. Several government agencies and ministries play an important role in promoting the process of digitalizing the economy and putting skills development and labour migration policies and strategies in place to secure an adequate supply of skilled labour (see Chapters 2 and 3).

Canada

Key government agencies in the field of ICT in Canada include ESDC and ISED. Education is regulated at a provincial level by state level ministries of education. The federal agency primarily responsible for issues relating to the migration of ICT specialists is Immigration, Refugees and Citizenship Canada (IRCC).

China

The ministry responsible for labour-related issues and skills development, including technical and vocational training, in China is the Ministry of Human Resources and Social Security (MOHRSS), while education responsibilities fall to the Ministry of Education. The ministry responsible for the ICT field is the Ministry of Industry and Information Technology. Key policies to promote digitalization in China are tailored to promote innovation.

Germany

The apex organizations for labour and education in Germany are the Federal Ministry of Labour and Social Affairs (BMAS) and the Federal Ministry of Education and Research (BMBF), as well as the state-level ministries of education. The German Government recently updated its Digital Strategy 2025, which lists projects closely connected to the ICT sector that are being carried out by BMAS and BMBF. Strategies include the new continuous training strategy, formulated by the Federal Ministry for Economic Affairs and Energy, which focuses on promoting digital skills development, and a project on how to use digital media in vocational training, and initiatives by the Federal Ministry of Family Affairs, Senior Citizens, Women and Youth, which include initiatives to promote a healthy work-life balance through remote work schemes.[31]

Another important stakeholder in ICT employment policy is the Federal Employment Agency (BA), which not only places unemployed people into work but also supports companies in overcoming skills shortages and offers continuous training programmes to employed workers. BA refers jobseekers to training programmes for both specialized digital skills and more general digital skills. One of the BA's roles is to monitor so-called bottleneck occupations (see Chapter 2).

30 International Labour Organization Declaration on Social Justice for a Fair Globalization, International Labour Organization ninety-seventh session, Geneva, 28 May to 13 June 2008.
31 For further information, see: www.bmfsfj.de/bmfsfj/themen/familie/familie-und-digitale-gesellschaft/vereinbarkeit-familie-beruf/vereinbarkeit-familie-beruf/119672

Box 1.4: The Work 4.0 dialogue process in Germany

The *Arbeiten 4.0 Dialogprozess* [Work 4.0 dialogue process] was initiated by BMAS in April 2015 and concluded in November 2016. One of its aims was to identify challenges in the future labour market, for example, job gains and losses due to digitalization, changing skills needs, working conditions, company structures and work organization, by encouraging cooperation among actors from business and industry, trade unions, civil society, research institutions, and political authorities. The process comprised several specific events and measures, including the publication of scientific studies and the organization of summit meetings. The process led to the publication of the *Weißbuch Arbeiten 4.0* [Whitepaper work 4.0] in 2016 (BMAS, 2017). It identified reforms needed, such as improving social security for self-employed workers in ICT sectors, set forth recommendations for political action, including the implementation of a systematic skills mismatch monitoring system to inform labour market policy and drew attention to the need for increased efforts to provide employees with lifelong learning opportunities.

Singapore

The key government actors involved in labour issues in the ICT sector in Singapore are the MOM and Workforce Singapore (WSG), which is overseen by the MOM and Ministry of Education. SkillsFuture Singapore (SSG), a statutory board run by the Ministry of Education, focuses on lifelong learning.

Among its activities, MOM encourages employers to adopt strategies for work life balance and workplace best practices, including through its collaboration with tripartite partners such as the Tripartite Alliance for Fair & Progressive Employment Practices.

In Singapore, the Ministry of Communications and Information also plays a significant role in this area and oversees the development of the infocomm technology, cyber security, and media sectors. Infocomm Media Development Authority (IMDA), the country's ICT industry regulator and promoter has also been promoting digitalization, as has the SME Go Digital programme, which provides subsidies for companies adopting digital technologies, partly covering both the direct cost of the technologies themselves and any associated consultancy work.

1.8.2 Employers' and workers' organizations

As mentioned above, constructive social dialogue can take several forms and is crucial in addressing the challenges in the field of ICT. Employers' and workers' organizations in the ICT sector have recently addressed issues related to skills development, networking, mobility, ageing, work time arrangements and mental health.

When looking specifically at collective bargaining, employers' and workers' organizations in developed economies play an important role in agreeing on wages and working conditions. In comparison to other sectors, collective bargaining is less widespread in the ICT sector. There are several reasons for this, including the relatively high wage levels in the ICT sector and of ICT specialists in other sectors.

Canada

The Canadian Labour Congress (CLC) represents 3 million workers across Canada. With regard to ICT workers, the organization is particularly concerned about job losses among low to medium skill level workers due to digitalization and globalization and is actively encouraging greater investment in continuous training (Research mission interview with CLC Canada). Data about the unionization of ICT workers are not publicly available.

An employers' organization that speaks on behalf of the Canadian employer community on international labour, employment and human rights issues is the Canadian Employers Council (CEC). The Council is a members-based organization that monitors how developments at the global level and in foreign jurisdictions are shaping the legal and political landscape in which Canadian businesses operate. It also analyses the impact of new forms of cross-border labour relations, international labour law and standards, and business and human rights initiatives on Canadian employers' operations at home and abroad.

Another association concerned with employment is Federally Regulated Employers – Transportation and Communications (FETCO), which is comprised of federally regulated firms within the transportation and communications sectors. Its members collaborate on matters related to human resources and labour relations, including issues reflected in several key pieces of legislation, including the Canada Labour Code, the Employment Equity Act, and the Human Rights

Act. Companies in the association collectively employ around 500,000 Canadian workers, mostly in unionized organizations, and all are regulated under the Canada Labour Code.

In general, employers in the country are concerned about skills shortages, including in the ICT sector, as reflected in various employer surveys, such as those undertake by the Business Council of Canada.

China

ACFTU has about 302 million members. The ICT-related trade unions within ACFTU mainly provide three services: (a) organizing trade unions, (b) improving skills, and (c) offering safeguards to workers. In the ICT industry, the organization rate of trade unions is around 30 per cent. In terms of skills development, they provide training courses for ICT entrepreneurs and run a training academy for highly-skilled ICT workers.

The China Enterprise Confederation/China Enterprise Directors Association (CEC/CEDA) is designated as the sole representative organization for all types of employers in China, regardless of sector, ownership and locality. In recent years, the CEC/CEDA has been working at promoting gender equality and non-discrimination practice, and enterprise development – particularly SMEs – in addition to corporate social responsibility, collective bargaining and tripartite social dialogue.

Germany

In Germany, DGB, which acts as an umbrella organization for eight trade unions, represents 6 million members. For the ICT sector, the primary industry trade unions in the country are ver.di (the German United Services Trade Union) with 2 million members and IG Metall (manufacturing industries) with 2.3 million members (Institut DGB, n.d.). The unionization rate of ICT specialists is around 10 per cent, which is well below the economy-wide average of 15 per cent (Loesche, 2016).

The main employers' associations in Germany are the Confederation of German Employers' Associations (BDA) and the Federation of German Industries (BDI). The most important employers' associations for the manufacturing ICT sector are the Mechanical Engineering Industry Association (VDMA) and the German Electrical and Electronic Manufacturers' Association (ZVEI). One of the largest ICT industry associations is Bitkom, which has more than 2,700 members from the ICT industry. BDA and the sector-specific associations perceive skills shortages as a major threat to the economic development of Germany.

Few firm-level collective agreements have been signed in recent years in the ICT sector. In 2017, only 19 per cent of workers were covered by a collective agreement in the ICT sector (Hans Böckler Stiftung), making it the sector with the lowest collective agreement coverage across sectors of the economy. Coverage rates were far below the public sector, which was almost universally covered, as well as banking (83 per cent in western Germany, 66 per cent in eastern Germany) and manufacturing (63 per cent in western Germany, 35 per cent in eastern Germany).

Generally, ICT specialists working outside the ICT sector are more likely to be covered by a collective agreement than those working within the ICT sector itself. In Germany, employers' and workers' organizations play an important role in addressing decent work challenges in ICT, promoting social dialogue and the development and the implementation of VET.

Singapore

The social partnership model in Singapore is characterized by tripartite cooperation. The National Trades Union Congress (NTUC) has 943,000 members, of which 18,000 are in the ICT services sector. NTUC is involved in collective bargaining and setting tripartite labour standards. Other important functions of NTUC include providing training and helping jobseekers find employment. In 2018, NTUC established TTAB. There are also several company-specific unions with many members who are ICT workers, including the Union of Telecoms Employees of Singapore and the Singapore Technologies Electronics Employees Union.

TTAB was set up to assess how NTUC can help ICT professionals stay relevant and have lifelong employment, especially for mid-career workers who have lost skill sets over time. TTAB works with the NTUC Employment and Employability Institute (e2i) to equip in-employment workers or mid-career job seekers with upgrades to their skills. To that end, e2i seeks to match employers and jobseekers through job fairs, coaching and programmes that improve the employability of job seekers. Every month, TTAB organizes activities around emerging technologies, including talks by industry experts, events and industry visits.

Company Training Committees (CTC) organized at the sector level, are concerned with skills development within companies in response to technological development and transformation. When companies undergo transformation, they share the scope of transformation with a trade union as well as the type of training the trade union can provide to support the company in its transformation journey. Special emphasis is placed on assisting mature workers. Multiple projects are currently being undertaken at unionized companies. All such companies send their employees for SSG digital workshops, providing, for example, coding-related training and up to 80 per cent of transformation projects are subsidized by development funds (Research mission interview with NTUC, Singapore).

In Singapore, the umbrella organization for employers, representing the interests of all sectors of the economy is the Singapore National Employers' Federation, whose activities include information sharing, providing training for members, leading programmes that help build better workplaces, and conducting research about key topics in the labour market. The Federation also conducts training specific to digital workplace skills. For example, SNEF Digital is a programme designed to help employers upskill their employees.

The main industry trade association tasked with representing and advocating specifically on behalf of corporate members in the ICT industry is SGTech. One of their workstreams focuses on building talent for the country's tech industry. The Singapore Semiconductor Industry Association (SSIA), which is considered to be the voice of Singapore's semiconductor industry focuses on talent outreach and continuous training, and on collectively addressing industry needs. Both SGTech and SSIA are involved in consultations with the Government in matters pertaining to the ICT sector.

The Singapore Computer Society is the largest ICT association for infocomm and digital media professionals in Singapore. Established in 1967, the Society has a thriving membership base of over 33,000 individuals. Activities encompass publications, training and various certification programmes that enable skills upgrading and career advancement, as well as networking opportunities for all members.

contents

2

Education and skills development

This chapter assesses the education systems and skills development policies of the four countries in the field of ICT, analyses the extent of skills shortages and skills mismatches and sheds light on a number of solutions that are already in place.

2.1 Education and training for ICT specialists

2.1.1 Vocational education and training and academic education in ICT and related fields

With some 4.7 million students enrolled in STEM subjects, China has the largest number of STEM students in the world (World Economic Forum, 2017; UNESCO Institute for Statistics, 2017). In 2016, more than one third of all students in Germany and Singapore had completed their degree in STEM fields, while in Canada a little more than one fifth of all students had completed a STEM degree (see figure 2.1).

Within STEM, the proportion of students who completed studies in ICT subjects[1] was highest in Singapore, followed by Germany and lowest in Canada. In China, the main study field within STEM was computer sciences, with around 1 million graduating each year (OECD, 2019a).

The sections below provide a general overview of the education systems in Canada, China, Germany and Singapore. In all four countries, there is a range of post-secondary education and tertiary education institutions offering flexible pathways that allow for exchanges among the different types of institutions.

Work-based learning is also an important part of higher education in all of the four countries. It is mandatory in Canada, China and in certain educational institutions in Germany. Higher education institutes in Singapore do not have a mandatory work-based learning component for all study programmes, but students do have the opportunity to apply for internships and apprenticeships.

Canada

Canada has a strong and well-funded public education system and the responsibility for education rests with provincial governments.[2]

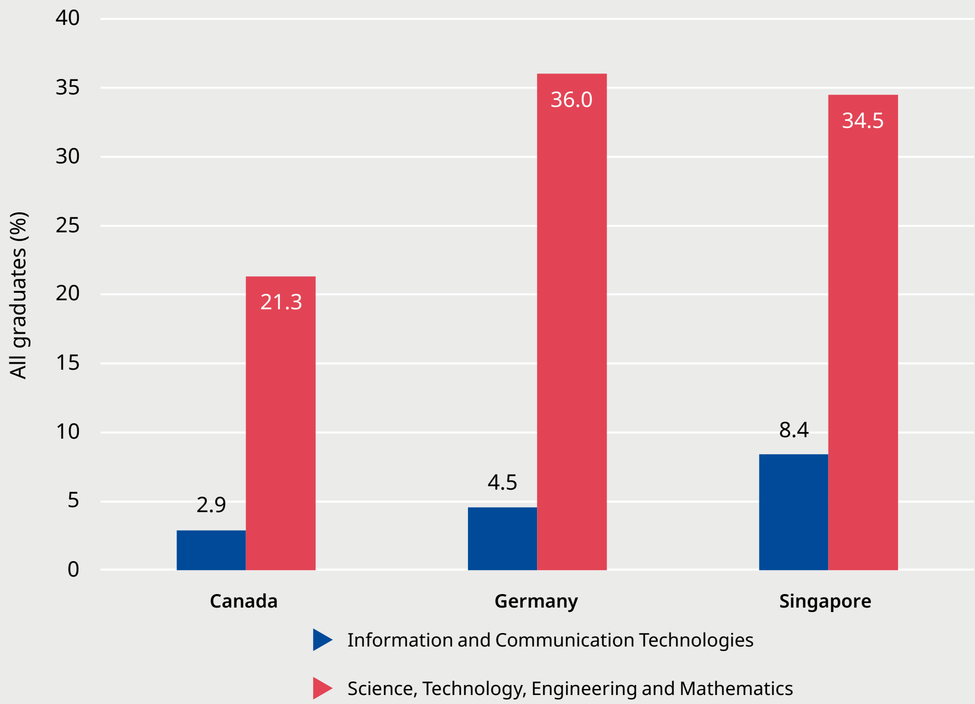
Colleges are perceived as institutions that provide practical, hands-on career training. Colleges may include applied arts and technology institutions, community colleges, institutes of technology and polytechnics. While some colleges may offer bachelor's degrees, they do not offer master's degrees or higher degrees.

The education system within the country is flexible. Students enrolled in a college can transfer their college credits to pursue a university degree. Alternatively, students can choose to attend a college after

1 The UNESCO Institute for Statistics defines ICT as a: "Diverse set of technological tools and resources used to transmit, store, create, share or exchange information. These technological tools and resources include computers, the Internet (websites, blogs and emails), live broadcasting technologies (radio, television and webcasting), recorded broadcasting technologies (podcasting, audio and video players and storage devices) and telephony (fixed or mobile, satellite, vision/video-conferencing, etc.)".

2 For further information, see: www.educanada.ca/programs-programmes/pathways-voies.aspx?lang=eng

▶ **Figure 2.1 ICT and STEM graduates as a proportion of all tertiary education graduates, 2016 (per cent)**



Source: World Bank Database and UNESCO Institute for Statistics, 2016.

completing a university degree for further specialized skills acquisition.

Between 2013 and 2018, the number of students enrolled in mathematics, computer and information sciences, and physical and life sciences and technologies increased. Conversely, the enrolment of students in visual and performing arts and communication technologies decreased between 2013 and 2018 (See figure 2.2).

Work-integrated learning is an important part of university and college education in Canada, and particularly in the ICT sector, given that rapid technological change has made it difficult to constantly update curricula. Furthermore, work-integrated learning can help students acquire soft skills that are necessary for succeeding in the workplace (see Section 2.2.3). Work-integrated learning can take various forms, including, co-op programmes, internships, apprenticeships, and industry-focused research projects. Those programmes are defined by a national organization called Co-operative Education and Work-Integrated Learning Canada and in some cases require approval, as is the case in the province of Ontario.

Co-op programmes are a form of work-integrated learning that are integral to university education in Canada. Students on co-op programmes spend a portion of their educational career working at a company in order to acquire practical workplace skills.

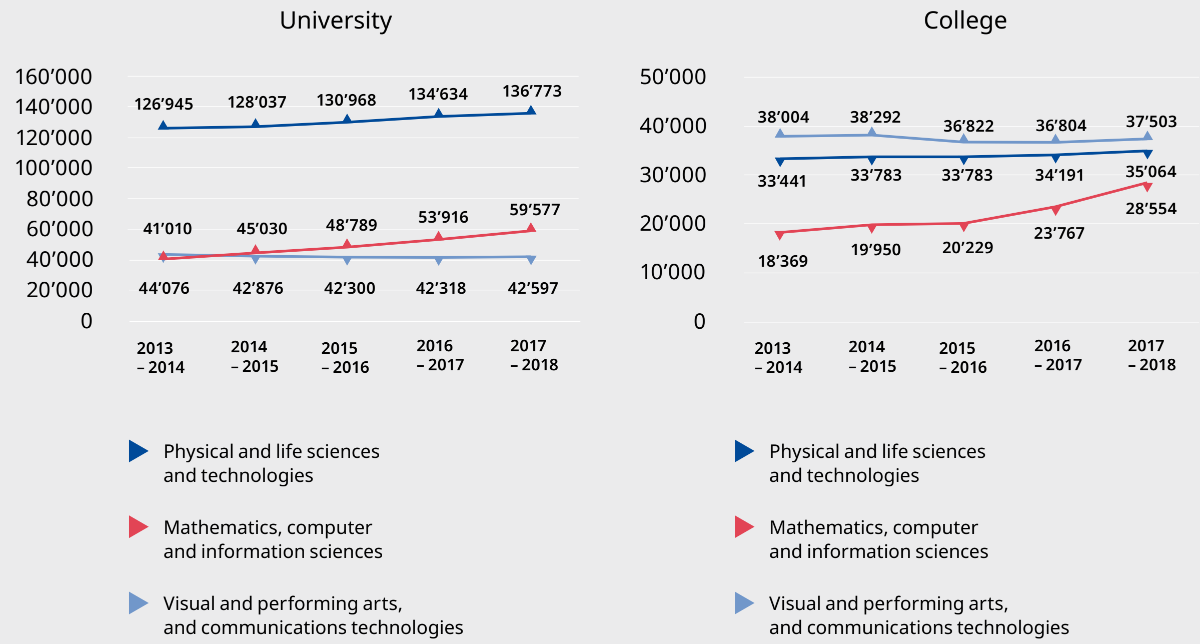
Apprenticeships are also an important educational pathway in Canada. However, that form of training is more prevalent in the construction and manufacturing sectors.

China

After completing compulsory education, which lasts nine years, students in China can choose to continue with senior secondary education, which lasts an additional three years. This may be done at secondary vocational schools. China has made significant efforts to expand participation in secondary vocational schools and the employment rate of graduates from vocational schools is very high – at 98 per cent. Yet despite the high employment rate of graduates from vocational training institutions, parents of students in China prefer that their children attend university instead. One possible explanation for this is the difference in social recognition and the negative impact on future career opportunities for those not graduating from a university (Research mission interview with Tsinghua University, China).

Tertiary education in China has experienced a huge expansion since the beginning of the 21st century. The

▶ **Figure 2.2 Number of students enrolled in ICT-related fields in post-secondary education in Canada between 2013-2014 and 2017-2018**



Source: Statistics Canada, 2018

▶ **Table 2.1 Employment status of graduates with bachelor's degrees in study fields relevant to the integrated circuit industry – China, 2016**

	Employment rate six months after graduation (%)	Average income six months after graduation (Yuan Renminbi)	Basic working skills mastered upon graduation (%)	Basic work ability satisfaction (%)	Relevance of major to employment (%)
Electronic information science and technology	91.9	4 643	51	79	59
Microelectronics science	89.8	5 211	55	78	53
Engineering	93.6	4 313	53	81	71

Source: MYCOS - Undergraduate employment indicators for main majors in 2016.

gross enrolment ratio of tertiary education throughout China increased from 21 per cent in 2006 to 51 per cent in 2018 (World Bank database and UNESCO Institute for Statistics, 2019).

According to a survey carried out by the Chinese Academy of Personnel Science, the number of students who majored in study fields relevant for the semiconductor industry was roughly 64,000, while the number studying mainly engineering was approximately 54,700 in 2016. From 2013 to 2016, enrolment in the 133 ICT-focused colleges and universities that were examined in the survey increased by an average of 5.1 per cent per year.

The integrated circuit industry is closely related to many scientific and technological disciplines, including physics, materials science and computer science. Students majoring in electronic information, science and technology, microelectronic science and engineering had very high employment rates (See table 2.1).

Germany

In Germany, after 10 years of schooling, students can make the choice to enter the VET stream or to continue general upper secondary education or upper secondary education focused on a particular field.

The main VET pathway is a dual vocational training programme that combines part-time vocational schooling with practical work experience (BiBB, 2015). In 2018, the most popular ICT-related vocational occupations in VET were in the field of informatics (computer sciences), followed by software development and programming occupations, IT system analysis, IT application consulting and IT sales.

In 2017, not all available apprenticeships could be filled in the occupational groups of informatics and software development and programming (Autorengruppe Bildungsberichterstattung, 2018). It is becoming increasingly difficult for companies to find apprentices in several training fields due to the increased attractiveness of tertiary education – both for young people and their parents.

In Germany, informatics skills acquired in VET courses may be comparable to bachelor's or tertiary degrees in a number of countries, given that the bachelor degree level was introduced only about a decade ago, when the tertiary education system was harmonized through the EU Bologna Process.[3] Prior to that, the first academic degree that a student could obtain was comparable to a master's degree in other countries (Interview with TUM, Germany). In the 1990s, ICT specialists generally held a university degree or equivalent or had undergone non-formal training. VET courses in the field of ICT were introduced in 1996.

Between 2017 and 2018, 227,000 students graduated from universities with a degree in computer science. It was the most popular field of study for recently graduated ICT specialists. Among other relevant study fields, electrical engineering was the most prominent, while some ICT specialists had a background in mechanical engineering, mathematics and physics, including, in particular, astrophysics.

The most popular fields of study in computer sciences were informatics, followed by business informatics and media informatics (see table 2.2) (Destatis, 2019a).

▶ **Table 2.2 Students studying computer science, by specialization – Germany, 2017-2018**

	All enrolled ICT students 2017-2018			New students 2017-2018		
	Number	Share of all ICT students (%)	Growth from 2008-2009 and 2017-2018	Number	Share of new students (%)	Growth from 2008-2009 and 2017-2018
Bioinformatics	2 658	1.2	37.5	470	1.4	15.8
Computer and communication technologies	5 818	2.7	60.4	985	2.9	68.1
Informatics	115 005	52.8	72.7	17 483	51.4	91.4
Engineering/ Technical Informatics	13 141	6.0	26.9	2 359	6.9	34.1
Media Informatics	18 644	8.6	82.2	2 864	8.4	56.6
Medical Informatics	2 920	1.3	127.8	520	1.5	90.5
Business Informatics	59 493	27.3	86.2	9 332	27.4	52.1
Total	217 679	100	72.8	34 013	100	69.0

Source: Destatis (Federal Statistical Office), Germany.

3 For further information, see: www.bachelor-studium.net/bologna-prozess and www.bpb.de/gesellschaft/bildung/zukunft-bildung/204075/bologna-folgen

Singapore

The education system for school students in Singapore is divided into three phases: primary education, lasting six years, secondary education, lasting between four and five years and post-secondary education (Ministry of Education, 2018). The post-secondary stage includes non-tertiary and tertiary education, and includes Institutes of Technical Education (ITEs), polytechnics and universities.

The system in Singapore is flexible, since students have access to numerous pathways to upgrade skills between the different levels of post-secondary education. One pathway to enter polytechnics, for those who did not graduate with good grades from secondary education, is through a two-semester special programme called a polytechnic foundation programme. In other cases, those students may continue their education at ITEs, junior colleges or pursue alternative qualifications that are not traditionally offered at mainstream schools. Furthermore, ITE students with sufficiently-high grades and qualifications can enter a polytechnic programme via a direct entry scheme.

After completing their polytechnic diploma courses, students have the option of pursuing a university degree. Admission criteria, course equivalence and credit transfer can vary by course and university. Between 60 and 70 per cent of polytechnic graduates continue their studies at universities (Research mission interviews with polytechnics, Singapore). For example, Singapore Institute of Technology (SIT) offers degree programmes in ICT and engineering, and provides flexible pathways for polytechnic graduates to obtain a degree, primarily a bachelor's degree. Programmes run on a trimester basis and are relatively short, as 94 per cent of students have completed relevant courses at polytechnics and therefore already have most of the skills needed for their work (Research mission interview with SIT, Singapore). The phenomenon of continuing studies at universities can have a positive signalling effect on young people, who may see this as means for obtaining more desirable or higher-paying employment.

Of the 20,202 individuals who graduated in ICT study fields in 2017, 44.6 per cent graduated from ITEs, 38.1 per cent from polytechnics and 17.2 per cent from universities (Ministry of Education, 2019).

ITEs are post-secondary institutions that provide full- or part-time vocational-oriented courses. In 2017, there were 6,531 students enrolled in electronics and ICT courses – a figure that has been slightly declining in recent years – and 8,643 in engineering courses, which has been increasing slightly over the same timeframe. Together these study fields accounted for 53.2 per cent of students enrolled at ITEs (Ministry of Education, 2018).

Polytechnics were designed for students interested in pursuing a more practically-focused path than university students. Work agreements with industry partners are part of the polytechnic framework and students can choose internships ranging from six weeks to six months, or even longer in some courses of study. In 2017, approximately 30,000 students were enrolled in IT and in engineering sciences. That same year, nearly 7,000 students graduated in engineering and nearly 3,000 graduated in IT. Together, those students accounted for 42 per cent of students enrolled at polytechnics (Ministry of Education, 2018).

There are six public universities in Singapore, formally known as autonomous universities. For both IT and engineering programmes at university, student enrolment has increased and have been on over the last five years. In particular, student enrolment for IT has increased by more than 50 per cent, from 1,086 students in 2013 to 1,579 students in 2017.

2.1.2 Work-based learning and continuous training

Given that technologies in ICT evolve quickly, there is a greater need for ICT specialists to update their skills regularly as compared to many other occupational groups. To keep up with technological changes, workers need to be equipped with skills that support lifelong learning. Since continuous education and training are less formal than initial education, this type of learning can take various formats.

Informal and work-based learning

Workplaces with technology-rich and innovative environments offer workers opportunities to further develop their formally-acquired skills. The Programme for the International Assessment of Adult Competencies (PIAAC), a survey of adult skills conducted by OECD in over 40 countries including Canada, Germany and Singapore, indicates that the likelihood of learning at work at least once a week is higher in ICT intensive workplaces[4] as compared to other workplace environments. Learning from co-workers and learning by doing are common forms of continuous learning among ICT workers.

In Germany, PIAAC survey results confirm that ICT professionals are much more likely to take part in ICT training initiatives (see table 2.3). Free training

4 This indicator describes tasks associated with ICT use, from reading and writing emails to word-processing, spreadsheet software and/or using programming languages.

contents

▶ Table 2.3 Methods used to acquire ICT skills in Germany, ICT professionals and non-ICT-professionals, 2018

Method used to acquire ICT skills	Percentage of ICT professionals who used that method to acquire skills	Percentage of non-ICT professionals who used that method to acquire skills
Individuals carried out free online training or self-study to improve skills relating to the use of computers, software or applications	55	14
Individuals carried out and paid for training to improve skills related to the use of computers, software or applications	4	2
Individuals carried out free training provided by public programmes or organizations to improve skills related to the use of computers, software or applications	11	3
Individuals carried out training paid for or provided by the employer to improve skills related to the use of computers, software or applications	43	20
Individuals carried out on-the-job training to improve skills related to the use of computers, software or applications	47	21

Source: Eurostat model questionnaires on ICT usage in households and by individuals, 2018.

provided by public programmes or organizations in addition to self-study play a more significant role in the lives of ICT specialists than for non-ICT professionals.

ICT specialists participate in employers' training initiatives and on-the-job training more often than non-ICT professionals. In general, the majority of the cost burden of continuous training is borne by the employer.

Skills development measures adopted by companies

Companies offer training to their workers primarily to update their skills in a fast-changing technological environment and to close potential skills gaps. Continuous training may also be part of a wider human resource management approach, especially in the case of large companies. For example, Institute for Municipal Data Processing in Bavaria (AKDB), a German ICT service provider for municipalities, has established a "Talent / Potential Management" framework to train employees who show special talent or potential for assuming important future leadership or expert positions. A wide range of training programmes are fully paid for by AKDB if the training is considered necessary for employees to be able to fulfil their work tasks. In addition, AKDB has established a special mechanism for employees who wish to advance their education through part-time studies. If the skills gained are also in the interest of the company, AKDB covers up to €15,000 (US$17,653)[5] in tuition fees and/or provides paid leave (Research mission interview with AKDB, Germany).

While continuous training programmes are available at large companies in all four countries, organizing and financing continuous training is more challenging for SMEs, which may not have a designated human resource management department and may not develop a long-term strategic plan for skills needs and continuous training programmes (Research mission interviews). Some companies train new employees in needed skills because they cannot find employees with those skills in the labour market. For example, Ensign Infosecurity, a service provider in the area of cybersecurity in Singapore, hires workers with experience in other professional areas, such as networks, and trains them in cybersecurity. Training in basic cybersecurity takes approximately six months to complete (Research mission interview with Ensign Infosecurity, Singapore). As illustrated in box 2.1, company engagement in continuous training is particularly high in ICT manufacturing.

The technologically advanced and highly innovative semiconductor industry requires a high skills level among its workers, which in turn requires workers to constantly upgrade their skills, both on and off the job.

In addition to workplace-related informal learning, companies also offer structured continuous training

5 Exchange rate calculated on 7 August 2020.

Box 2.1: Examples of skills development at companies in the semiconductor industry

a. In China, a survey of companies in the integrated circuit industry revealed that 95.5 per cent of companies in that industry provide internal training and 57.1 per cent provide external training. State-owned enterprises invest more in staff training than private enterprises.

Induction training for new employees accounts for 34 per cent of training expenditure, while the remaining funding is directed towards continuous training. About 44.4 per cent of company budgets is spent on professional and technical training, 11 per cent on leadership and senior management training and 10 per cent on soft skills training.

Source: Country report prepared for China

b. In Germany, 70 per cent of learning at Infineon, a semiconductor company, takes place on the job, while 20 per cent of learning takes place near the job and 10 per cent takes place off the job. Infineon offers internal, external and web-based training. Employees can choose to take a wide variety of online courses.

Source: Research mission interview with Infineon, Germany.

Box 2.2: Continuous training strategy at Deutsche Telekom

To manage and prepare for future skills and jobs shifts, Deutsche Telekom has developed an integrated approach with the following three goals:

a. To establish new global job architecture with future profiles and skills that can be used across the Deutsche Telekom group

b. To carry out strategic qualitative personnel planning in order to understand which profiles will be more in demand in the future and which will decrease or even disappear, in order to identify reskilling potential and implement reskilling actions

c. To create transparency with regard to required skills, identify skills gaps and put suitable qualification measures in place.

The objective of the strategy is to improve the employability of the workforce and identify reskilling opportunities for employees in job profiles that will be less in demand. A skills management programme, established by the company in 2017, has offered guidance to more than 30,000 employees.

Currently, Deutsche Telekom offers around 30,000 training courses in its training portfolio. Therefore, the employee often needs support on how to find the right training course. The company has implemented a new learning platform and a search support tool that combines formal and informal learning content, including internal intranet articles or videos on specific topics.

Source: Research mission interview with Deutsche Telekom, Germany

to their employees. In Germany, the telecommunication company Deutsche Telekom is implementing a systematic retraining skills management strategy (see box 2.2).

However, it can be challenging for employers to provide such measures as it can take a long time to develop employees' skills. Furthermore, the turnover rate of employees is quite high in some professional fields, which can pose additional challenges for employers intending to invest in skills development. Other challenges that ICT companies face include identifying which workers need to upskill and retrain, and adapting training to employees with different learning needs and educational and work experience backgrounds (Research mission interview with Bell Canada).

Continuous training offered by external providers

As explained above, ICT specialists have different qualification levels and upskilling occurs at all levels. There are a number of "self-made" ICT specialists, who have not completed vocational or tertiary education in ICT related fields. Those specialists may have acquired expertise through non-formal learning and experience and/or obtained a certificate after completing continuous training programmes at a large tech company, such as Cisco, Microsoft or Huawei, or through

Box 2.3: Continuous training offered by external providers

a. The Chinese company Huawei has established a global network of over 400 Huawei ICT academies and over 100 Huawei authorized learning partners. There are 82 certification exams in 22 fields available, including in ICT infrastructure, ICT development and ICT verticals. The company has also established the Huawei CEBIT ICT online training ecosystem.

b. Lighthouse Labs in Canada offers boot camp style training for web development programmers, custom corporate training for the digital upskilling of non-digital roles and various "learn to code" initiatives. They also offer three-month programmes for highly-motivated jobseekers, where participants can receive a "Diploma of Web Development". The courses have proven successful and 93 per cent of participants are hired within 120 days of competing their training.

c. ICTC, in partnership with Microsoft Canada, has established a programme to bridge the digital divide for job seekers looking for an opportunity to add to their existing technical skills and diversify their professional experience. Following an assessment of a worker's previous experience and technical skills, that worker is given a Microsoft voucher that allows him or her to take advantage of the Microsoft Career Pathways Program. Supported by research from ICTC, selected areas of focus for Microsoft certifications include cybersecurity, AI and data science.

d. The German Fraunhofer Academy provides training in key innovative technological areas. The Academy fosters rapid knowledge transfer between findings and the development of new technologies at Fraunhofer Institutes, which are considered to be some of Germany's leading research centres, and the adaptation of these findings in companies. The Academy provides three-day seminars and certified courses of between three and eight weeks' duration. In 2018, the Academy trained more than 4,000 individuals, mostly in data science and cybersecurity. Of those participating in the big data or cybersecurity courses, close to 90 per cent hold a master's degree. Participants are mostly sent by large companies, which usually pay participants' training fees.

Source: Research mission interviews.

continuous training provided by social partners. For example, NTUC in Singapore provides continuous training to workers, who may also obtain certificates as part of their continuous training activities.

The skills needed by those who are employed, unemployed or seeking to change job are extremely diverse, as is the landscape of continuous training providers. The duration of continuous training offered by training institutions may vary from a few days for an ICT specialist, to up to six months for a worker with a non-tech background who is learning to code.

The SSG initiative in Singapore facilitates efforts by companies to provide their staff with skills upgrading, and also supports individuals who want to develop their skills. The main initiative for sector-specific training is the Techskills Accelerator (TeSA), an umbrella organization that was established by IMDA in partnership with strategic partners, including WSG, SSG and stakeholders from industry. TeSA supports the professional development of ICT professionals. Under TeSA, support is provided for short-form ICT courses offered by external providers in emerging areas, including AI and cybersecurity, through CITREP+ funding from IMDA.

Box 2.3 provides some examples of the types of continuous training in the area of ICT that are currently offered by external providers.

Continuous training and education frameworks at universities and VET institutions

Canada

The British Columbia Institute of Technology (BCIT) is strongly committed to continuous education and offers extremely popular part-time courses in all its schools. While many students attend BCIT after high school, some are mid-career professionals who are looking to move into higher-level work positions. Students typically pay the approximately CAD600 (US$448)[6] per class cost of continuous education themselves (Research mission interview with BCIT).

Waterloo University in Canada also runs a professional development programme. A wide range of courses are

6 Exchange rate calculated on 7 August 2020.

offered for individuals with previous work experience, including business management and project management courses. The University also offers multi-week online certificate courses, including courses on big data management systems.[7]

China

Another example of continuous training is the programme offered by Beijing Information Technology College in China. That renowned college provides vocational training courses for both students and those already employed. In particular, the college offers an upskill training course for teachers in vocational training schools to ensure they keep abreast with technological developments. All teachers at the College, including those teaching non-ICT subjects, are required to learn teaching methods that utilize ICT. Curriculums at the College are based on local government guidelines and are revised on an annual basis (Research mission interview with Beijing Information Technology College, China).

Germany

In Germany, a formal route for professionals with vocational training is to obtain a master's level degree, as either a Techniker [technician] or Fachwirt [specialist]. The continuous training part of the VET system grants three different degrees to workers with ICT VET training: IT specialists (German qualification framework level five), IT operative professionals (German qualification framework level six) and IT strategic professionals (German qualification framework level seven).[8]

In the field of ICT a relevant master's course is, for example, in IT technology (Informations–technikermeister/in). Such ICT specialists usually perform supervisory and coordinating work in the fields of information technology and consumer electronics and can train apprentices. Education can usually be completed on a full-time or part-time basis, as a classroom course or as part of a distance learning course. There are different financing models for career development[9] and usually the employer pays at least part of the course fees.

The provision of continuous education master's programmes and modules leading to certificates for employed adults, or those seeking work, is a fairly new development. While regular university education up to doctorate degree level is free in Germany, continuous education master's programmes receive no funding from the Government and are thus often paid for by course participants themselves.[10]

Singapore

Access to VET institutions and higher education institutions for individuals taking part in continuous training is most developed in Singapore. ITEs provide short, part-time courses for workers and jobseekers. The duration of such courses ranges from 12 to 20 hours. Polytechnics offer part-time programmes at the diploma and post-diploma levels designed for adult learners who want to deepen their knowledge base and improve their skills. Courses tend to be taught in the evening. These including courses leading to specialist diplomas in AI, data science and cybersecurity (Research mission interview with polytechnics, Singapore).

SIT has established a continuous learning branch known as SIT Learn. SIT grants a SGD2,000 (US$1,456)[11] credit to every graduate alumnus to enable him or her to return to SIT and enrol in a continuous learning course (Research mission interview with SIT, Singapore).

National University of Singapore (NUS) also provides a significant number of continuous training and retraining courses to workers. The Singaporean Government heavily subsidizes courses for individuals who are 40 years of age or older (Research mission interview with NUS, Singapore).

▶ 2.2 Skills mismatches, shortages and gaps

Broadly speaking, a skills mismatch refers to a situation in which the skills offered by employed workers and those seeking employment do not match the skills required by employers, and when there is either a shortage or surplus of workers with a specific skill set. This phenomenon creates inefficiencies as workers themselves or the country's society has invested in the development of skills that are not required in the labour market, while the skills needed are lacking. Key issues to be considered include: whether the education and training systems currently in place provide the volume and type of skills needed in the job market, whether workers possess skills that will allow them to

7 For further information, see: www.pd.uwaterloo.ca/AdvancedOnlineCertificates.aspx
8 For further information, see: www.it-specialists.eu/index.php/it-weiterbildung
9 For further information, see: www.aufstiegs-bafoeg.de/
10 For further information, see: www.master-and-more.de/weiterbildungsmaster/#c5771
11 Exchange rate calculated on 7 August 2020.

adapt to economic, technological and organizational changes in the future, and whether employers are investing in the reskilling and upskilling of workers (ILO, 2019).

The reasons for ICT skills shortages on the supply side can be manifold. They include the following:

a. The education system does not produce a sufficient number of ICT specialists. This could be because there are just not enough young people graduating from the educational system or because young people are studying subjects that are not in demand (horizontal skills mismatch), because young people do not have the skills level needed (vertical skills mismatch); or because they are not working in the ICT occupation for which they were trained;[12]

b. The labour market is failing to tap the full potential of the female labour force. This is related to a horizontal skills mismatch and vocational choices; and

c. Demographic factors such as an ageing workforce.

From the demand side, skills shortages may lead to upward wage pressure and SMEs and start-ups may face difficulties in hiring ICT specialists at those wage levels, as company surveys in Germany show (Bitkom 2019b, BMWi, 2018b). In Singapore, 67 per cent of SMEs in the ICT services industry report difficulty in matching salary expectations for local tech talent (SGTech, 2019). But the possibility of offshoring and outsourcing to neighbouring countries is likely to alleviate the pressure of offering higher wages (Research mission interview with Institute for Adult Learning, Singapore).

Skills gaps refer to when workers do not have the skills required for competent job performance. Skills gaps may be due to difficulties in keeping pace with rapid technological development, not having the combination of skills needed, and the low quality of training and education. Box 2.4 provides an explanation of how skills mismatches, skills gaps and skills shortages are measured.

2.2.1 Assessing the shortage of ICT specialists

A shortage in a specific skills area or occupation occurs when demand exceeds supply. In all four countries, there are severe shortages of software developers and programmers in addition to shortages of specialists in new technologies and corresponding job roles.

It is difficult to measure the extent of shortages. Nevertheless, governments and researchers have tried to assess skills shortages using various methods.

▶ Box 2.4: Understanding skills mismatches, gaps and shortages

Skills mismatch for those in employment occurs when an employed person has a job in which the requirements do not correspond to the skills that the person possesses. The mismatch may occur with job specific/technical, basic and transferable skills.

a. Under-skilled: when the level and/or the types of skills the person has are at a lower level than those required to adequately perform the job.

b. Over-skilled: when the level and/or the types of skills the person has are at a higher level than those required to adequately perform the job.

Other forms of mismatch that can affect the labour force may include the below.

a. Skills shortage and skills surplus: when the demand for workers with a particular skill or set of skills exceeds or is inadequate relative to the supply of those available with that skill.

b. Skills gap: when workers do not have the right skills required for competent job performance.

c. Mismatch by level of education vertical mismatch.: when the educational level is either less than or more than the level required.

d. Mismatch by field of study horizontal mismatch.: when the field of study is not appropriate for the job.

Source: ILO guidelines for the measurement of qualifications and skills mismatch of persons in employment, adopted by International Conference of Labour Statisticians, 10-19 October 2018, Geneva.

12 According to German Labour Force Survey data, only around 52 per cent of persons with a degree in the field of computer science and computers work in a core ICT occupation in the country (Bundestag, 2019b), the remainder work in other occupations, are unemployed or are inactive. Not working in a core ICT occupation does not necessarily mean that these workers are not using their ICT skills in their current occupations (Bundestag, 2019b), especially given the fact that ICT is becoming increasingly interdisciplinary.

Surveys of companies - skills in demand and skills shortages

Certain ICT sector associations have conducted surveys and subsequently published reports on skills shortages. ICTC in Canada, SGTech in Singapore, Bitkom in Germany, and sector associations in China have all conducted such studies.

Canada

A survey conducted by ICTC in 2019 of companies across the digital economy revealed that in-demand job roles include: business development manager, project manager, digital marketer, business analyst and researcher. Currently, and for the next four years, the following job roles were identified as most in demand: software developer, data scientist, data analyst, user experience (UX)/user interface (UI) designer, full stack developer, cybersecurity analyst, developing operations engineer, machine learning engineer, database administrators and IT support specialist.

Over half of respondents stated that the specialists who were most difficult to find were those with three to six years of working experience (See figure 2.3) (Cutean and others, 2019).

China

According to research mission interviews conducted in China in 2019, the ICT service industry in China is experiencing serious shortages. According to data provided by Zhaopin.com, in late 2016 the Internet and e-commerce sector ranked first for unmet demand for talent, while computer software ranked fifth and IT services ranked tenth. ICT specialists were among the ten occupations most in demand across the economy (Boston Consulting Group, 2017). Shortages encompass all qualification levels, including at the master's and doctorate levels (Country report prepared for China). Shortages are particularly severe for positions requiring higher levels of education (Boston Consulting Group, 2017). The industry association of the integrated circuit industry noted that there was a severe lack of highly-educated talent (Country report prepared for China).

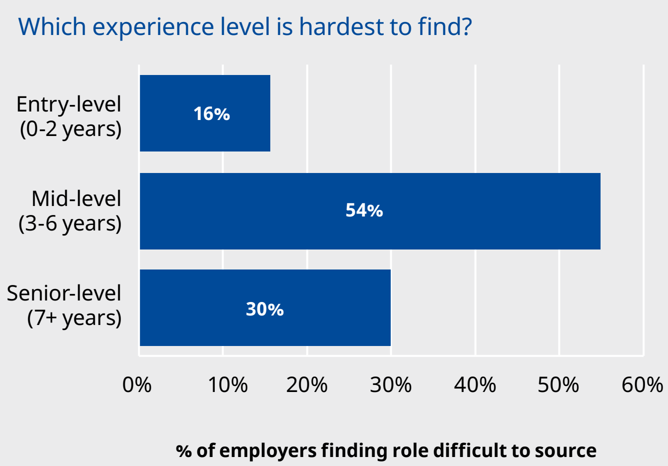
In a recent white paper, the software development association CCW estimated that demand surpassed supply by 7.65 million ICT specialists in 2017 (CCW, 2018). Reasons for the skills shortages are due to an insufficient number of students studying to work as ICT specialists in addition to the gap between the instruction received at ICT schools and the skills requirements of employers (Chen and Ma, 2017).

Advanced digital areas that are in demand include cloud computing, big data, the IoT and AI (CCW, 2018). Demand has also been rising, and will continue to do so, for cross-sector skills and experience that combine digital skills with other sectors of the economy – in digital farming, e-commerce, and ride-sharing businesses, for example (OECD, 2019a).

Germany

A study conducted by Bitkom estimated a shortage of 124,000 IT specialists as of September 2019 (Bitkom, 2019b). Across sectors, 83 per cent of surveyed companies reported a shortage of ICT specialists, and 65 per cent expect that shortage to grow. Chambers of

▶ **Figure 2.3 Specialists most difficult to source according to companies - Canada, 2019**



Source: ICTC, 2019

commerce and industry and other regional actors have made their own assessments of shortages (See, for example, the skilled labour monitoring report by the Chamber of Industry and Commerce, Bavaria). According to an assessment conducted by BA, occupations with bottleneck vacancies include (a) technical and VET occupations such as occupations in mechatronics and automatization technologies and electrical technicians; (b) occupations requiring bachelor's or equivalent qualification-level skills, including workers in automatization technologies, electrical technicians and software developers, and; (c) occupations requiring a master's level and above, including IT-application consultants, and software developers (BA, 2019a).

Singapore

According to the results of a recent survey of 200 companies in Singapore, companies were investing in AI and machine learning, data analytics, cloud adoption, cybersecurity and mobile applications (SGTech, 2019). As the focus on data-driven applications and capabilities continues to grow, demand for talent to fill key roles, including data analysts and scientists, is also likely to rise.

Vacancies and other shortage indicators

One method for assessing labour demand is to monitor job vacancies. Assessment of job vacancies can serve as a proxy indicator for labour demand. However, it only partly reflects net job creation, as job turnover is high in this segment of the labour market. Other measures for assessing labour shortages are the length of vacancy before the post can be filled and the job search to vacancy ratio. An upward trend in job vacancy rates or prolonged unfilled vacant posts can signal that employers are facing difficulties in finding the required skills to fill a position at a given wage and working conditions. This can indicate skill shortages, but at the same time such problems may also be caused by poor recruitment and HR practices, low wages and poor working conditions. In addition, it is important to note that high vacancy rates can be accompanied by high unemployment rates due to labour mismatches or high turnover rates.

Canada

In Canada, an assessment of labour supply in relation to labour demand for each occupation in the ICT sector is elaborated in the context of the Canadian Occupational Projection System (COPS). This ten-year projection system covering the entire economy is carried out by ESDC. Labour surplus, balance or shortage in a given occupation is assessed on the basis of an analysis of key labour market indicators including employment and wage growth in addition to the unemployment rate and job vacancies (2019 to 2028 projections are based on the period from 2016 to 2018, for example).

The high vacancy rates for software engineers and computer programmers indicate that the required skills for those jobs are not available in the labour market. This is also the case for ICT technicians overall, web designers and developers and user support technicians, as those professions all have above-average vacancy rates (Research mission interview with ISED, Canada).

Germany

According to data provided by BA, from July 2015 to July 2019 the number of vacancies in Germany in all ICT sectors increased almost twice as much as the average across all sectors – or 63.3 per cent and 35.7 per cent, respectively. The sectors that saw the most significant increases were telecommunications, software publishing and computer programming, consultancy and related activities.

Singapore

In 2018, there were 220,800 employed information and communication professionals and 20,000 unfilled vacancies in Singapore. Changes in the ratio between vacancies and the number of persons employed indicate that between 2015 and 2018 the shortage became less severe, with the ratio decreasing from 0.116 in 2015 to 0.094 in 2018 (IMDA, 2015; IMDA, 2019). According to the 2017 Job Vacancies Report, published by the MOM, 16 per cent of all professional, manager, executive and technician vacancies remained unfilled for more than six months –with 28.2 per cent of software, web and multimedia developer roles unfilled for at least six months.

In China, there is currently no publicly available data on job vacancies.

Unemployment of ICT specialists

Another indicator used to measure skills shortages or surpluses is the unemployment rate, with a low unemployment rate among highly-skilled workers reflecting a shortage.

Headhunting for highly-skilled ICT specialists is common and since ICT specialists seek better opportunities while still employed, the job turnover rate may be higher than what is reflected in unemployment rates. A high job turnover rate among ICT specialists was identified as a major challenge for companies interviewed in all four target countries.

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The unemployment rate among ICT specialists is particularly low in Canada and Germany. This could be indicative of a shortage of ICT specialists in the two countries. In Canada, the 2018 unemployment rate for ICT specialists was 2.6 per cent, while the unemployment rate for the overall economy was 3.6 per cent. Similarly, according to administrative data in Germany, the unemployment rate among core ICT specialists is very low when compared to the average unemployment rate, at 2.7 per cent and 5.2 per cent respectively.[13]

In contrast, the 2018 unemployment rate for Singaporean residents in the ICT sector was the third highest among all sectors in the economy, at 5.5 per cent, with only the accommodation and retail trade having higher unemployment rates, at 6.3 per cent and 6.0 per cent respectively (MOM, 2018). That statistic could either indicate a less severe skills shortage in Singapore as compared with Canada and Germany, or could point to skills gaps among those jobseekers. In-depth data on vacancies, wages and demand for employers' goods and services would be needed to make a conclusive assessment.

In China, it is challenging to obtain unemployment data disaggregated by sector or occupation.

2.2.2 Forecasting skills shortages

Long-term projections rely on the formulation of multiple hypotheses. Assumptions must be formulated for both the supply of labour, which includes factors such as the supply of graduates at different educational levels and in different study fields, labour force participation rates for women, labour migration, the skills of older workers, occupational mobility, ageing of the workforce and retirement, and the demand for labour, including developments in product and service markets and consumer preferences, globalization and technological trends.

Given the trends discussed in the previous chapter, the nature of jobs and skills requirements are expected to change significantly across the sector globally. Forecasting the impact of those structural changes on tasks and skills is challenging. Many forecasting models are based on historical employment data for given occupations, as classified according to occupational standards. Some countries have collected new forms of data that allow for a greater level of granularity.

All four target countries have drawn up estimates regarding the future demand and shortage of ICT specialists. Estimates from all four countries indicate that demand for ICT specialists is expected to increase significantly. Furthermore, forecasts from Canada, China and Germany show that there will be an acute shortage of ICT specialists in the future.

Canada

ESDC carries out a short-term and a long-term labour market forecast using COPS, a ten-year projection system that covers the entire economy, including 293 occupational groupings, which are a mix of three and four-digit National Occupational Classification codes.

According to COPS data, the number of job openings for core ICT occupations is projected to increase by 40 per cent between 2018 and 2028, with roughly half of that increase stemming from replacement

▶ Table 2.4 Growth in ICT subsectors in Canada, 2018-2023

Subsector	Additional demand by 2023	Total employment in 2023
Advanced manufacturing	8 000	300 000
Interactive digital media	95 000	830 000
Health and biotechnology	9 000	120 500
Agri-foods and food-tech	20 000	672 000
Cleantech	25 500	316 500
Clean resources	10 500	176 000

Source: ICTC, 2019.

13 Unemployment rates are based on individual national definitions and not harmonized unemployment rates based on the labour force survey according to the ILO definition, which would allow for international comparability. However, harmonized unemployment rates have not been formulated for occupational categories such as ICT specialists, for example. Hence, the above data may not be fully comparable.

demand because current job holders will be retiring. Future shortages will likely persist for the following occupations: computer engineers (with the exception of software engineers and designers); information systems analysts and consultants; database analysts and data administrators; software engineers and designers; computer programmers and interactive media developers, and graphic designers. Acute shortages are expected for information systems analysts and consultants and for software engineers and designers.

ICTC has also developed a short-term projection of job roles and employment in the ICT sector and digital employment in other sectors of the economy to 2023 (Cutean and others, 2019). Within the ICT sector, employment in ICT and non-ICT occupations is expected to reach approximately 982,000 by 2023, an increase of 12.9 per cent as compared with 2018. Digital employment in other sectors is expected to grow by 20 per cent and reach 1.1 million workers by 2023. Table 2.4 shows projected growth in ICT areas in Canada over the next few years.

Some ICT occupations are expected to grow rapidly, including cybersecurity specialists. According to ICTC estimates, by 2023 Canada will see additional demand for between 40,000 and 53,000 cybersecurity practitioners, with over 100,000 people working as cybersecurity specialists by that date (ICTC, 2019d.).

China

Neither the MOHRSS nor the Ministry of Education have developed national skills forecasting mechanisms, although the Ministry of Education is carrying out research on the demand for occupations and qualifications by using company surveys and qualitative research methods (Research mission interview with Tsinghua University, China). However, the software development association CCW estimates that the shortage of ICT specialists will reach 12.46 million by 2020 (CCW, 2018).

Germany

Labour market forecasting and foresight studies are carried out at national, regional and in some cases local levels. Non-governmental stakeholders, including Bitkom, are also very active in conducting surveys about future technological trends in the ICT field.

In 2019, the Federal Institute for Vocational Education and Training (BiBB) and the Institute for Employment Research (IAB) published a labour market forecast that focused on the impact of digitization, (Zika and others, 2019). The overall results of the survey (the economy 4.0 scenario) show that by 2035, 300,000 workers will be replaced by new technologies. On the other hand, however, 3.3 million new jobs will be created between 2018 and 2035.

Demand for core ICT specialists is expected to be particularly high. In the economy 4.0 scenario, by 2035 demand for core ICT specialists (26.3 per cent) will grow at a greater rate than supply (26.1 per cent). Those estimates confirm the results of a previous forecast carried out in 2015 for BMAS, which used a different macroeconomic model (Vogler-Ludwig and others, 2016).

Singapore

The national Skills Framework for ICT was developed by SSG, IMDA, and the Cyber Security Agency of Singapore in consultation with industry stakeholders and educational institutions. The Framework provides useful information on career pathways, current and emerging skills and occupations and job roles for ICT professionals. It is refreshed every 18 to 24 months to include emerging tech areas, in line with industry needs and trends.

In addition, IMDA also conducts an annual survey on infocomm media manpower, in which it collects statistics on infocomm media jobs and vacancies. According to the 2019 survey, expected demand for ICT occupations is projected to increase by 68,000 jobs between 2019 and 2021, an increase of over 28 per cent.

2.2.3 Identifying skills needs and skills gaps

In addition to identifying a shortage of talent, it is also important to identify the different types of skills in demand. One way of identifying in-demand skills is to carry out surveys of companies; another is to analyse big data on online job portals and social networks. Surveys conducted in all four countries show that, in addition to significant demand for technical skills, there is also a demand for soft skills. Those surveys also indicate that fresh graduates often require further training to acquire skills specific to the workplace.

Employers' and workers' organizations in the ICT sector can play a crucial role in identifying skills needs and gaps and facilitating skills development. As discussed in Section 1.8, social partners in all four countries are actively assessing skills needs and providing opportunities for skills development.

Technical skills

Demand for skills in new technologies has been rising rapidly. AI is one of the major trends driving that demand. Demand for skills in cloud computing, big data and cybersecurity is increasing in all four

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▶ **Table 2.5 Technological trends in ICT and examples of relevant skills that are growing in importance in Singapore**

Emerging Trends	Examples of Relevant Skills	
Artificial Intelligence and Data Science	▶ Analytics and Computational Modelling ▶ Business Innovation ▶ Business Needs Analysis ▶ Business Process Re-engineering	▶ Cyber Forensics ▶ Data Strategy ▶ Data Governance ▶ Data Design ▶ Data Engineering ▶ Data Visualisation
Cyber Security	▶ Business Needs Analysis ▶ Cyber Forensics ▶ Cyber Incident Management ▶ Cyber Risk Management ▶ Security Assessment and Testing ▶ Security Governance	▶ Security Programme Management ▶ Stackeholder Management ▶ Threat Intelligence and Detection
Immersive Media	▶ Analytics and Computational Modelling ▶ Application Development ▶ Business Innovation ▶ Business Needs Analysis ▶ Data Design	▶ Infrastructure Design ▶ Embedded Systems Programming ▶ Product Management ▶ User Experience Design ▶ User Interface Design
Internet of Things	▶ Analytics and Computational Modelling ▶ Data Strategy ▶ Data Engineering ▶ Embedded Systems Interface Design	▶ Embedded Systems Programming ▶ Security Architecture ▶ Security Administration

Source: SSG, 2017.

countries (Research mission interviews). Workers able to use specific programming languages, particularly Java, are in high demand in all four countries, as indicated in various research mission interviews. For telecommunication companies and software companies, the most difficult skill sets to find are related to software development. Business intelligence and analytics skill sets have also become hard to find in recent years (Research mission interview with Modis, Canada). Table 2.5 provides an overview of technical skills that are becoming increasingly important in the ICT service sector, as identified in Singapore's Skills Framework for ICT specialists.

Soft skills and generic skills

It is widely acknowledged that soft skills have become increasingly important for ICT specialists in recent years. While there is no set definition as to what those skills are, common features are linked with the development and use of technologies and include critical, analytical and creative thinking, coping with the change in technologies (which reflects flexibility and an ability to learn), a need to understand processes, teamwork, leadership and communication skills, service orientation, business and management skills, and digital literacy (SSG, 2017; Cameron and Faisal, 2016; VDI, 2019; acatech, 2016; CCW Research, 2018).

Using data from the Programme for the International Assessment of Adult Competencies (PIAAC) from 2012 and 2015, OECD compared the skills sets of software developers, data professionals and ICT technicians with other professionals with a tertiary degree. Unsurprisingly, when compared with other professionals, workers in those three ICT occupations were found to possess excellent numeracy skills (particularly data professionals and software developers) and problem-solving in rich technology environment skills (especially data professionals and software developers). However, ICT specialists had less well-developed management and communication skills, and poorer accountancy and selling skills compared with other professionals. Such gaps were highest among software developers (OECD, 2019c).

Canada

The ICTC Digital Talent Strategy 2020, which reviewed 78 employers in the Canadian digital economy, revealed that soft and interpersonal skills, and business and entrepreneurial skills, were ranked slightly higher than technical and innovation skills (Asliturk, Cameron and Faisal, 2016). Indeed, creativity and innovation skills were considered to be as important as technical skills by many companies.

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It is often difficult to find technical and soft skills in combination in the labour market. In Canada, for example, 23 per cent of surveyed employers in the digital economy stated that finding employees with good technical, business and interpersonal skills was the main skills-related challenge they faced. In addition, 14 per cent of respondents considered training to acquire skills in new technologies was their major challenge, 6 per cent mentioned a lack of experience-based skills, and 4 per cent highlighted a lack of leadership skills as potential challenges (Cameron and Faisal, 2016).

Germany

In a survey of 220 companies in Germany, conducted to ascertain the skills development needs of staff for the implementation of industry 4.0, the majority of companies underscored the need to develop competencies in data analysis (60 per cent), process management (53 per cent), customer relation management (47 per cent), dealing with specific IT systems (46 per cent), IT business field analysis (44 per cent) and IT security (42 per cent). When asked about the need to develop employees' skills and capacities, most respondents named the following as being at the top of their wish lists: interdisciplinary thinking and action taking, enhanced process know-how, leading competencies, participation in innovation, problem solving skills and self-responsible decision making (acatech, 2016). Generic skills were also found to be highly relevant for "all around" ICT specialists working at SMEs across several sectors, since those professionals may be required to handle a wide variety of tasks independently (Research mission interview with acatech, Germany).

According to a survey of 856 companies conducted by Bitkom in September 2019, one third of companies indicated that job applicants often lacked soft skills, including social competencies and teamwork skills. While skills gaps in soft skills were important, many employers (41 per cent) reported that applicants were insufficiently qualified with regard to technical skills. Approximately 9 per cent of employers found it difficult to find ICT experts with knowledge of new technologies such as blockchain and AI (Bitkom 2019).

Singapore

The main skills gaps perceived by surveyed companies in the ICT service sector in Singapore were technical skills (52 per cent), followed by soft skills (41 per cent) (SGTech, 2019). In the occupational guide entitled "Skills Framework for Infocomm Technology",[14] skills are grouped into (a) technical skills and competencies, and (b) generic skills and competencies – at basic, intermediary and high levels. The combination and level of technical and generic skills vary by job role, level of specialization and job seniority. SSG monitors data on ICT specialists, encompassing job roles related to IT-security, IT-support, IT-infrastructure, data management, professional services software and applications, sales and marketing. The classification shows that ICT specialists need to acquire both technical and generic skills. Table 2.6 provides examples of the skills required for three specific occupations.

▶ Table 2.6 Technical and soft skills required in three specific occupations in Singapore

Occupation	Skills required
Software application architect	High level technical skills (advanced) Transdisciplinary thinking (advanced) Sense making (advanced) Creative thinking (advanced) Problem solving (advanced) Interpersonal skills (intermediate)
Data analyst	Medium/upper level technical skills Computational thinking (basic) Problem solving (basic) Communication (intermediate) Sense making (intermediate)
Embedded system engineer	Medium level technical skills Problem solving (basic) Teamwork (basic) Interpersonal skills (intermediate) Communication (basic) Lifelong learning skills (basic)

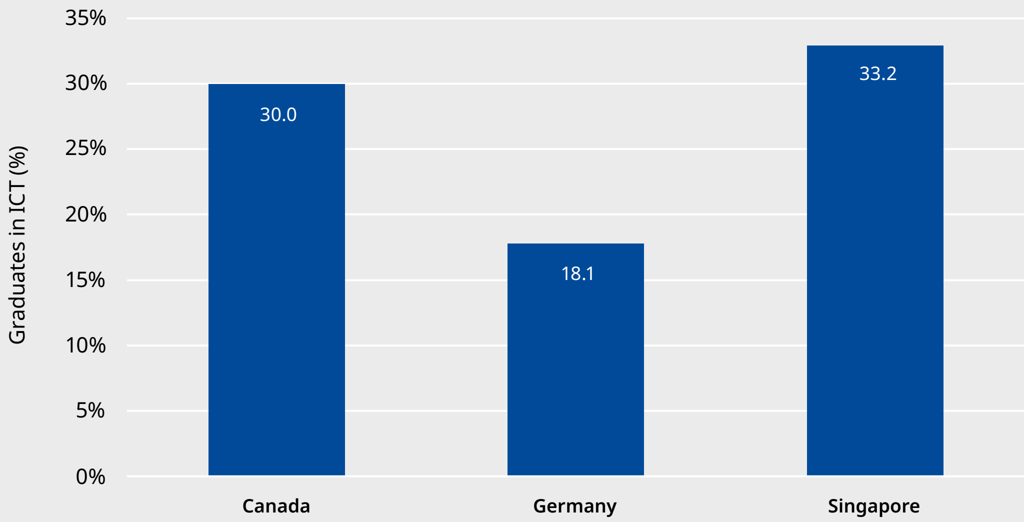
Source: SSG, 2017b.

Graduate skills gaps

VET and higher education institutions are concerned about the employability of graduates. While VET institutions and universities cannot substitute for skills usually acquired through work experience, they can design curricula and teaching methods to prepare students for their first job. Nonetheless, initial training at a company may still be necessary.

14 The Skills Framework for Infocomm Technology was developed by SSG, WSG and the IMDA and provides useful information on sectors, career paths, occupations and job roles, existing and emerging skills and training programmes for skills upgrading and mastery.

▶ **Figure 2.4 Proportion of women among all graduates completing a tertiary education programme in ICT – Canada, Germany, Singapore, 2016**



Source: World Bank Database and UNESCO Institute for Statistics, 2016.

The successful assessment of skills gaps depends on the availability of reliable survey results. Surveys on the employability of students conducted among employers by Tsinghua University in China show that employers value the excellent theoretical foundations that graduates have acquired, but perceive a gap when it comes to the practical application of that knowledge.

It can take approximately eight months or more before young graduates can be considered fully skilled employees. In Singapore, employers surveyed by SGTech observed that recent graduates often had significant skills gaps, including in terms of their technical competencies, commercial awareness, capacity for teamwork and critical thinking. In general, however, graduates were deemed to have positive attitudes towards skills learning (SGTech).

Similar observations have been made by employers in Canada. Research conducted by ICTC in 2016 found that employers were concerned about the transition between education and industry. Graduates needed more entrepreneurial, creative and interpersonal skills to succeed in the workplace. However, on-the-job training was viewed as a costly option, particularly by SMEs.

In Germany, companies have reported that problem-solving skills are not sufficiently developed within the school system (Research interview with Ludwig-Maximilians University, Germany). Abstract thinking ability, and a capacity for structured, analytic and logical thinking, self-organization and self-reflection are also considered invaluable skills that should be taught to university students enrolled in universities of applied sciences (Research mission interview with MUAS, Germany).

▶ 2.3 Initiatives to attract more women to ICT-related study fields

2.3.1 Gender differences in enrolment in ICT study fields

There is a strong gender bias in the development of ICT skills for professional employment in all four countries. In 2016, women comprised one third of graduates from ICT programmes in tertiary education in Singapore, 30 per cent in Canada, and only 18 per cent in Germany (see figure 2.4). Comparative data for China are unavailable. However, research mission interviews in China suggest that the proportion of women to men studying ICT is likely to be low, even though gross enrolment rates for women across all disciplines in educational institutions is higher than it is for men.[15]

Canada

Among those between 25 and 54 years of age with STEM credentials who were in the labour force in 2016 –although not necessarily in a STEM occupation –only 16 per cent of those with engineering and engineering technology credentials and only 29 per cent of mathematics and computer science graduates were women. In 2010, women accounted for only 15.6 per cent of first-year students studying computer and information science; in mathematics and related studies women accounted for 42.9 per cent of the total, and the average of both study fields was 27.6 per cent (Statistics Canada, 2016).

The percentage of women enrolled in mathematics, computer and information sciences at universities increased modestly between 2013 and 2018, but women still accounted for less than 30 per cent of all students. The proportion of women is higher for physical and life sciences and technologies, and in visual and performing arts and communication technologies. However, those broad fields also include many non-ICT studies and therefore those statistics should be interpreted with caution (See figure 2.5).

Germany

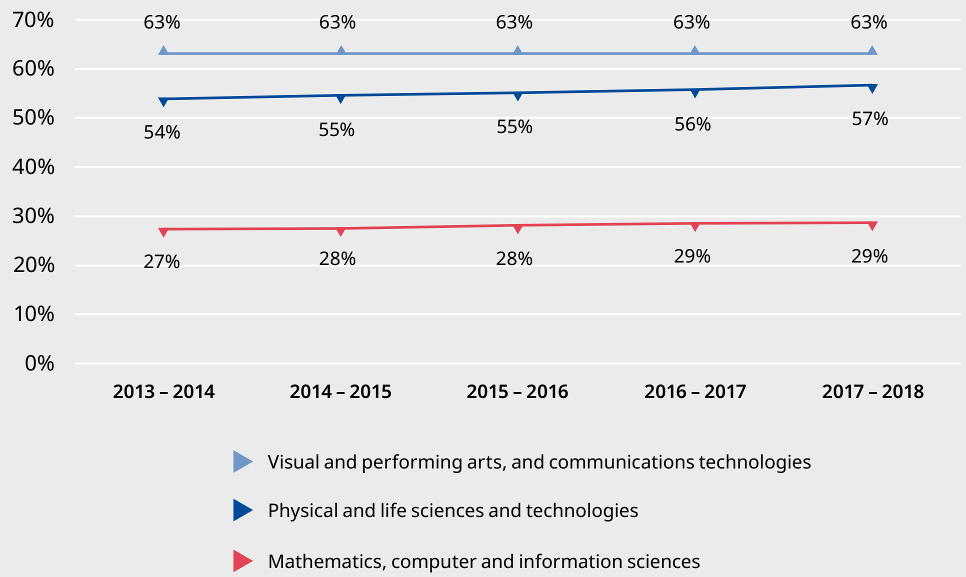
The proportion of women choosing ICT study fields has increased in Germany in recent years, although the gender gap remains much larger than in many other study fields in the country, and is greater than the gender gaps in Canada and Singapore in ICT. The proportion of women enrolled in ICT tertiary education increased from 15.4 per cent in 2008-2009 to 21.1 per cent in 2017-2018. Detailed data about enrolment in interdisciplinary ICT study fields suggest that women are more attracted to study ICT fields when combined with natural sciences, health, or media rather than with technical fields (see figure 2.6) (IW, 2019).

Furthermore, the proportion of women attending VET ICT programmes is particularly low. Overall, the proportion of female apprentices in ICT occupations decreased from 9.0 per cent in 2014 to 8.7 per cent in 2018 (Destatis, 2018).

Singapore

In Singapore, the proportion of females enrolled in ICT study fields at universities is trending downwards, and declined from 34.1 per cent in 2013 to 29.8 per cent in 2017 (Ministry of Education, Education Statistics Digest 2018). The participation of women in ICT programmes within the VET system was also low and the proportion

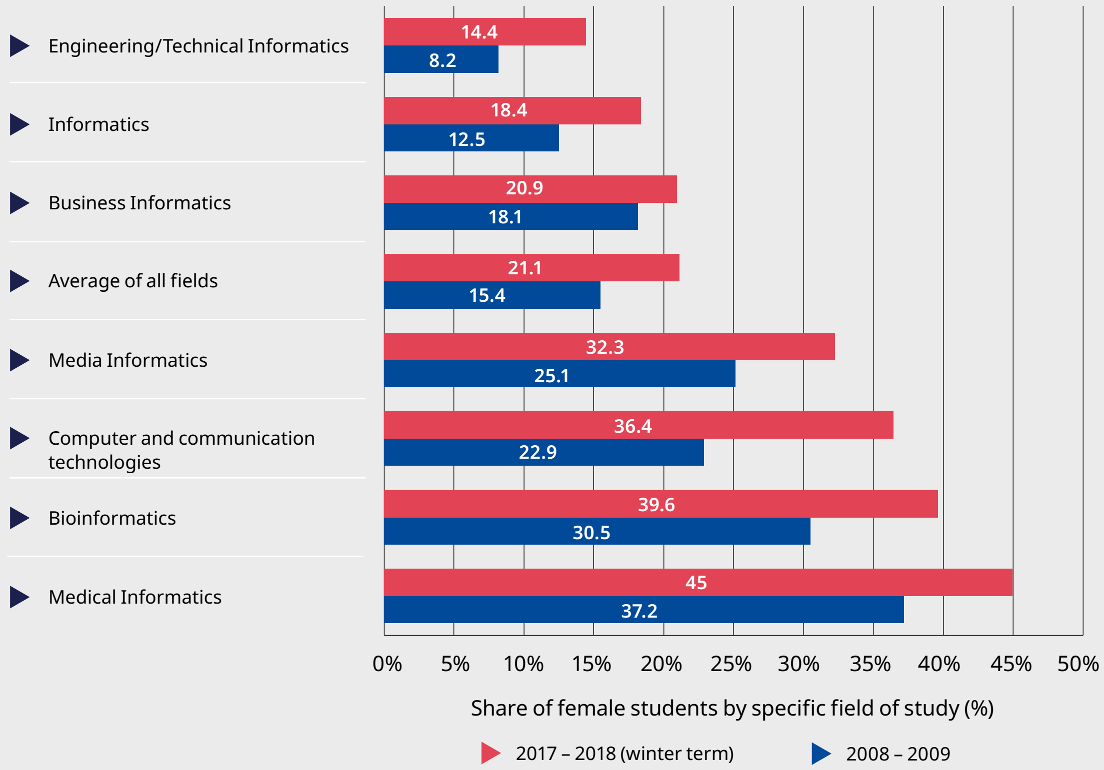
▶ Figure 2.5 Percentage of women students enrolled in ICT -related study fields at universities in Canada between 2013-2014 and 2017-2018



Source: Statistics Canada, 2018

15 For further information, see: www.uis.unesco.org/en/country/cn

▶ Figure 2.6 Tertiary education: ICT courses with high and low proportions of female students– Germany, 2008-2009 and 2017-2018



Source: Destatis (German Federal Statistical Office) and author compilation, 2018.

of females enrolled in ICT programmes at ITEs and polytechnics was 25.9 and 33 per cent, respectively.

China

No comparative data are publicly available for China. Evidence suggests, however, that here too there is a gender divide. For example, at the renowned Beijing Information Technology College, only some 30 per cent of students enrolled in ICT study fields are women.

2.3.2 Attracting young women to ICT study fields

In addition to gender mainstreaming and diversity initiatives, there are various policy options and targeted actions that can be taken at various stages that can serve to encourage girls and women to pursue ICT-related fields.

Guidance in schools and vocational orientation

It is crucial that steps are taken at an early age to encourage both girls and boys to envisage a career in the field of ICT. An interest in and an orientation towards computer sciences usually becomes apparent at a young age. Furthermore, studies have shown that gender stereotypes towards young children can have a strong impact (acatech, 2019). Girls may become demotivated and their initial interest may diminish due to the dominance of boys in computer courses, competitions, study subjects and activities being chosen that tend to appeal to young boys. Evidence from Germany indicates that female interest in ICT tends to decrease with age. For example, while the ratio of girls to boys taking part in informatics youth competitions is almost equal during first through fourth grades in school, it decreases with each passing school grade until the share of women taking part in the competition in high school is only 28 per cent (Bundestag, 2018b).

It has been stressed that vocational orientation and guidance might not be adequate to encourage more girls to enrol in computation sciences and related VET and study fields, and that gender stereotypes must also be addressed at the primary and pre-school age education levels (acatech, 2019; Research mission interviews with MUAS, Germany and Radical IO, Canada).

The MINT-Mädchen[16] (STEM girls) project in Germany includes a scouting phase where girls who are interested in STEM fields are identified at school. Those girls then receive both coaching that includes technical input and coaching about gender-typical role perceptions and behavioural patterns. Meanwhile teachers and professors at universities receive support regarding gender-sensitive STEM teaching. The project is funded by BMBF and is carried out by the Technical University, Amberg-Weiden. A wide range of similar opportunities for women interested in STEM subjects are made available through the Komm-mach-MINT[17] ("Join in, do STEM") programme, which is also implemented by BMBF.

An example of a programme that promotes digital literacy among young women is the Canada Learning Code. Launched in 2011 to equip women with digital skills, the Programme has now expanded to champion digital literacy among young girls, women, persons with disabilities, indigenous young people and newcomers to the subject area. Since its launch, the Programme has reached over 280,000 participants. Canada Learning Code found that 67 per cent of the women and girls who participated in the Programme felt more comfortable with using coding and technology, and 81 per cent of young people felt encouraged to learn more about coding and technology after completing a Programme course.[18]

There is evidence that gender stereotypes influence school performance in mathematics. Research suggests that girls' self-perceptions about their numerical skills and abilities should be strengthened, even at a young age (Budde, 2009).

Transition from education to the labour market and awareness raising

The Government of Canada runs the Student Work Placement Program, previously known as the Student Work Integrated Learning Program, which provides assistance to students and under-represented groups, including women in STEM, indigenous students and persons with disabilities. In addition, the Global Talent stream of the Temporary Work program includes a company-specific Labour Market Benefits Plan to support diversity. This can be useful for promoting the employment of women in ICT.

Another example of gender inclusivity is Ladies Learning Code, a programme that offers courses and workshops to empower and educate women in the tech sector. In addition, the Future Female Techmakers Conference organizes workshops for girls and young women at high school and university to encourage their interest in mathematics and computer science[19].

▶ 2.4 Policies and strategies for ICT education, training and skills development

International labour standards provide guidance on policies and strategies for the training and development of workers. Based on the ILO Human Resources Development Convention, 1975 (No. 142), Member States have the obligation to develop comprehensive and coordinated policies and programmes of vocational guidance and vocational training. Additionally, the ILO Paid Educational Leave Convention, 1974 (No. 140) states that Member States shall formulate and apply a policy designed to promote, by methods appropriate to national conditions and practice and by stages as necessary, the granting of paid educational leave for the purpose of (a) training at any level; (b) general, social and civic education; and (c) trade union education.

The ILO Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy provides guidance on the skills development policies of large multinational enterprises. It states that multinational enterprises "should ensure that relevant training is provided for all levels of their employees in the host country, as appropriate, to meet the needs of the enterprise as well as the development policies of the country. Such training should, to the extent possible, develop generally useful skills and promote career opportunities and lifelong learning. This responsibility should be carried out, where appropriate, in cooperation with the authorities of the country, employers' and workers' organizations and the competent local, national or international institutions."

16 For further information, see: www.mint-maedchen-projekt.de/files/MINT-Maedchen/MINT-Maedchen.pdf
17 For further information, see: www.komm-mach-mint.de
18 For further information, see: www.canadalearningcode.ca/about-us
19 For further information see http://ladieslearningcode.ca/; see also https://uwaterloo.ca/women-in-engineering/future-female-techmakers-conference-fftc

2.4.1 Skills development strategies and curricula adaptation at VET institutions and universities

Canada

In Canada, the provinces decide on the funding they allocate to VET and higher education institutions. In the case of Ontario, the province has a strategic mandate agreement with post-secondary institutions. This is a unique agreement with each institution wherein the institutions set particular performance targets and commit to them in cooperation with the government. Those agreements help to better align programming with labour market demand, including demand in the ICT sector (Research mission interview with Ontario Ministry of Training, Canada).

Universities have a great deal of autonomy in designing the curricula of their study fields. In general, universities are free to allocate funding received from their respective provinces across programmes. However, for major expansions in programmes, a university must make a proposal to its province for additional funding that, inter alia, analyses the relationship between the labour market, student demand and interprovincial migration. The Research Universities' Council British Columbia, for example, has assessed those variables and advocated for the expansion ICT programmes, including by increasing the number of spaces on engineering programmes.

China

In China, the main responsibility for managing and delivering primary and secondary education lies with counties, whereas higher education falls under the jurisdiction of provincial authorities.

The Ministry of Education works closely with the provincial education authorities, universities and college sectors to set all policy matters relating to higher education enrolment and ensures that enrolment policy is in line with the priorities of the central Government (OECD, 2016).

The number of trainees and training areas in public vocational training institutions is decided by local governments, in line with labour market trends (Research mission interview with MOHRSS, China). The CEC/CEDA, employers' organization has emphasized that coordination among VET institutions and companies could be further strengthened.

According to Tsinghua University, regarded as one of the best universities in China, university curricula are decided by a relevant industry guidance committee, whose members include government representatives and stakeholders from companies and training institutions. Those curricula are updated regularly (OECD, 2019a). On the basis of surveys conducted among companies to identify needed skills, discussions are currently underway to develop new degree courses in emerging technologies, including big data, AI and smart manufacturing, in particular at the master's and doctoral levels (Research mission interview with Tsinghua University, China).

Fifty-six industry committees, including one for ICT, provide guidance to vocational schools. These committees include stakeholders from training institutions, government institutions and companies (Research mission interview with the Ministry of Education, China).

Germany

As is the case in Canada, in Germany it is the states that are responsible for education within the formal education system.

The responsible federal ministry, which is generally the Federal Ministry for Economic Affairs and Energy (BMWi), adopts vocational training regulations for the company-based training element of state-recognized training occupations[20] that fall under the dual training system, in coordination with BMBF. Those regulations include minimum requirements and determine objectives, content, duration of training, and test requirements for the practical part of training, which are of particular relevance to employers. While the advantage of this system is that it can help maintain the high quality of VET courses, challenges lie in ensuring that courses are flexible enough to adapt to technological change.

Vocational training regulations are formulated by BiBB in consultation with employers' and workers' organizations. The training regulations currently in place for ICT specialists were last updated in 1997. A large proportion of ICT specialists now work across many non-ICT sectors, which makes the process for updating regulations complex, since it requires consultations with a large group of stakeholders. According to BiBB, the regulations have recently been reviewed and there are plans to roll out implementation in August 2020.

20 There were 326 state recognized training occupations in 2019.

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For tertiary education, universities have a large degree of autonomy in designing their curricula. At Munich University of Applied Sciences (MUAS), for example, an expert council needs to be formed when introducing a new programme and when conducting consultations with representatives of relevant industry organizations. However, new study programmes must be approved by the ministry of education of the relevant state. Developing a new course takes around two years and an accreditation council decides every five to seven years if a study programme still fulfils the appropriate requirements (Research mission interview with MUAS, Germany).

Singapore

The Ministry of Education routinely collaborates with other ministries and organizations to introduce ICT-related programmes and courses in schools. The Student Development Curriculum Division, an entity within the Ministry, works with schools, institutes of higher education, and other partners and stakeholders. Industry practitioners, including members of the industry association SGTech, sit on academic curriculum boards at universities. The Government has placed considerable emphasis on working with employers' and workers' organizations to design and implement skills creation programmes.

In 2014, the Government launched the SSG initiative to provide Singaporeans with the opportunity to achieve their full potential, regardless of their background. SSG aims to: (a) help individuals make well-informed choices in education, training and careers; (b) develop an integrated high-quality system of education and training that responds to constantly evolving needs; (c) promote employer recognition and career development based on skills mastery; (d) foster a culture that supports and celebrates lifelong learning.

The Government has drawn up sector transformation maps on how companies in 23 economic sectors can ensure that their employees' skills are up to date. The Skills Framework for ICT is refreshed every 18 to 24 months to include emerging tech areas, in line with industry needs and trends. Since 2017, NTUC, MCI and IMDA have organized engagement sessions with human resource practitioners and business leaders in the ICT industry with the aim of co-developing a Skills Framework and Industry Transformation Map for ICT.

Individuals can get support for their skills upgrading by attending courses at training providers accredited by Government agencies, such as IMDA. For example, the CITREP+ programme supports the continuous and proactive upgrading of technical skills sets, including in the emerging areas of AI and cybersecurity, so that the ICT workforce can remain productive and keep pace with technological change. IMDA works with training providers to develop and offer high-quality infocomm professional development technology courses that award certificates that attest to participants' knowledge and skills in relevant areas.

2.4.2 Striking a balance: foundational skills, domain-specific skills and soft skills

There are divergent views as to whether the education system should focus on strengthening deep foundational skills or whether it should impart specialized skills. Broad study courses, with deep foundational skills in mathematics, physics and related fields may equip students with more long-term skills. However, the immediate employability of recent graduates in those fields may decrease since they may require further training to acquire some of the more specialized skills needed for employment. As complexity increases, and ICT expands into new sectors and professions, broad foundational numerical and ICT skills are likely to allow for flexible skills growth.

One example of a university that has developed specific courses is Beuth University of Applied Sciences in Berlin, which has developed a new bachelor's programme in cybersecurity. In contrast, some of the most renowned research-oriented universities in Germany are now introducing broad interdisciplinary foundational study courses at the bachelor's level. One such planned study course is at Humboldt University in Berlin, which is planning to include mathematics, physics and computer science as the main pillars of study (Research mission interview with Humboldt University, Germany). In addition to providing theoretical and practical technical skills, VET and higher education institutions are increasingly focused on introducing "soft" skills into their study programmes and teaching methods. Box 2.5 outlines examples of such innovative teaching methods.

One common challenge for all higher education institutions is a shortage of academic teaching staff (VDI, 2019). Such shortages can be particularly acute for teaching staff in new fields of study, including AI (Research mission interviews with AI Singapore and NUS, Singapore). Universities and colleges, including Tsinghua University in China and Beuth University of Applied Science in Germany, are starting to design online courses for teachers and teaching staff in computer science fields. Beijing Information Technology College runs a teaching centre, dedicated to providing continuous training for teachers at vocational schools across the country. At least 100 teachers receive three to four weeks of training per year.

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▶ **Box 2.5: Examples of teaching and learning methods with strongly interlinked skills components**

a. Canada: BCIT uses project-based learning in order to impart problem-solving skills and teach creativity. BCIT also has a strong focus on "core competencies", including creativity, problem solving, communication, and leadership. Their summit centre initiative is aimed at fostering those skills and provides a variety of other important support for self-directed learning, including a makerspace, media production facilities, and presentation and speech coaching (Research mission interview with BCIT, Canada).

B. Germany: The Faculty of Computer Sciences and Mathematics of the Munich University of Applied Sciences (MUAS) has developed its own methodology for testing to assess the cognitive skills of ICT students in the areas of abstract and analytical thinking and logic at the beginning of the first year of a student's studies. Students receive their individual results, which they can compare with the expected benchmark. Preparatory courses are offered to close skills gaps. Teaching staff receive average results for the cohort. The averages indicate to the teaching staff what is needed in terms of training and upskilling. Instructors can then fine tune the curricula of their courses accordingly (Research mission interview with MUAS, Germany).

2.4.3 Interdisciplinary and multidisciplinary study fields

Three strategies can be adopted to foster interdisciplinary and multidisciplinary approaches: enhancing the amount of multidisciplinary learning content in ICT study fields, enhancing the amount of ICT-related content integrated into other study fields and creating relevant interdisciplinary and multidisciplinary study courses.

Canada

Promoting interdisciplinary study now features on the agenda of most tertiary education institutions. One example is BCIT in Canada, where creating interdisciplinary credentials is one component of their innovative education plan. BCIT has established a business school that bridges the gap between the business and technology needs of companies. The innovative "tech corridor" programme will ensure that business and computing students are in the same physical space while they work on projects for industry (Research mission interview with BCIT, Canada).

The University of Waterloo also has an interdisciplinary programme that has demonstrated the value of interlinking training among fields so that students develop an understanding of how tech can be incorporated and implemented across sectors.

China

The need for interdisciplinary measures has also been recognized in China, particularly the integration of engineering and ICT (CCW, 2018). For the integrated circuit industry, more than 40 scientific and technological fields – including electronic information, physics, chemistry, materials, automatic engineering, and many interdisciplinary and cutting-edge manufacturing technologies – are relevant. Highly-skilled talent should possess a number of key qualities, including a comprehensive knowledge background, cross-technical skills and the ability to innovate (Country report prepared for China).

Current challenges that must be addressed in order to implement an interdisciplinary approach include the need to incorporate courses on AI into other disciplines. To that end, Tsinghua University offers a ten-hour AI training course to students to enhance their capabilities in that area.

Germany

There is a long tradition of multidisciplinary study programmes in Germany, where combined study courses in business informatics has been taught since the 1990s. It is critical to train experts to support digital transformation in companies (Research mission interview with Ludwig-Maximilians University, Munich, Germany). New combined study programmes have also been launched, mainly in combination with media, health, and engineering departments. In addition to teaching deep tech and foundational skills, universities may seek to increase the number of multidisciplinary subjects in ICT study courses in order to broaden students' knowledge and understanding of its potential applications (Research mission interview with TUM, Germany).

Singapore

Singapore has developed 33 Skills Frameworks across different sectors. These provide key information on sectors, career pathways, occupations, current and emerging skills required for occupations, in addition to a list of training programmes for skills upgrading and skills mastery. The aim of those frameworks is to create a common skills language for individuals,

Box 2.6: Programmes to promote entrepreneurial skills

a. At BCIT in Canada, an entrepreneurship centre supports students to write business plans, conduct market research, create business intelligence and attend presentations by successful entrepreneurs.

b. At Shenzhen Polytechnic in China, training courses on innovation and entrepreneurship skills are available. About 4.7 per cent of students decide to start a business after graduation and another 12.7 per cent do so after three years of work experience.

c. Beijing Information Technology College runs a centre for innovation and entrepreneurship. Students are encouraged to create proposals for innovative projects and the College supports them in finding business incubators. Although entrepreneurship classes are not mandatory, student interest is high. During the 2018-2019 academic year, about 17 projects were undertaken.

d. The ILO country office for China and Mongolia has been working to improve the quality of youth entrepreneurship training programmes in China through upgrading and sharing ILO entrepreneurship promotion training tools and programmes, including Start and Improve Your Business, GET Ahead and Know About Business.

e. UnternehmerTUM [Entrepreneurship at TUM] in Germany is a private centre for start-up activities. It offers a range of services to some 50 technology start-ups or business founders each year. For example, UnternehmerTUM offers the accelerator programme TechFounders, which includes coaching for technology start-ups over a period of 20 weeks, and establishes contact with industry partners for start-ups in fields including autonomous driving, electric mobility, smart home and smart factory technologies and data analytics.

f. NUS in Singapore provides annual grant money of SGD750 million (US$546 million) to between 70 and 80 master's or doctoral students on the NUS Graduate Research Innovation Programme. That Programme encourages professors and post-doctorate students to start businesses. In its first run, NUS supported 22 projects with an investment of SGD100,000 (US$72,844) in each project.

Source: Research mission interviews.

employers and training providers and to promote skills portability. For example, a cross disciplinary approach is being promoted for legal, finance and accountancy, in order to introduce students to digital skills. Another example is 5G, which is undergoing broad implementation across sectors: putting 5G talent plans in place is likely to prove increasingly important.[21]

AI Singapore (AISG), a national programme on AI funded by the National Research Foundation, has established an AI Apprenticeship Programme, or AIAP, in which the goal is to target, train and prepare local Singaporean AI talent. That full time deep skilling programme in AI lasts nine months. For the first two months, the apprentices focus on self-directed learning. For the next seven months, they work on real world AI projects from the 100 Experiments Programme. The AIAP is highly acclaimed. Each intake class includes students from various academic backgrounds, but all have some prior knowledge of AI and machine learning.

Teaching entrepreneurship skills and promoting start-ups

In addition to introducing interdisciplinary and multidisciplinary programmes, higher education institutions in all four countries have been implementing programmes and initiatives to strengthen entrepreneurial skills. Box 2.6 provides examples of such initiatives in the target countries.

2.4.4 Cooperation among industry, universities and vocational training institutions

In all four countries, cooperation takes place among industry, universities and vocational training institutions in the form of work-based learning, inputs on curricula and specific courses developed in collaboration with industry. The ILO Human Resources Development Recommendation, 2004 (No. 195) emphasizes the role of social dialogue in formulating, applying and reviewing national human resources development, education, training and lifelong learning policies.

Skills gaps among graduates were found in all four countries, making the transition from higher education to the workplace difficult, with graduates often

21 For further information, see: www.imda.gov.sg/programme-listing/5G-Innovation

requiring several months of on-the-job training. For that purpose, the role of internships, apprenticeships and other forms of work-based learning are being emphasized in all four countries.

Another form of cooperation with companies has been in the form of projects that students can work on and may eventually be implemented by private companies or public entities. Such project-based learning allows for transferring foundational and practical knowledge into real life projects.

Canada

Post-secondary institutions in Canada have established cooperative programmes, namely academic programmes in which students are given an opportunity to work in an industry related to their education. Co-op programmes involve collaboration among educational institutions and employers to help students gain working experience while they are in education. Those programmes usually last between four months and one year and participating students must be paid. As defined by Co-operative Education and Work-Integrated Learning Canada, there are two types of co-op programmes: co-op alternating and co-op internships. In both models, students receive experience in a workplace setting related to their field of study. The number of required work terms or semesters varies by programme. However, it must account for at least 30 per cent of the time spent in academic study for programmes lasting more than two years, and at least 25 per cent for shorter study programmes. While internships and co-op programmes at universities are proving very useful, research conducted by ICTC suggests that further workplace integrated learning may still be needed (ICTC, 2016). Table 2.7 illustrates the prevalence of internship and co-op programmes in Ontario, based on a survey of 1,538 employers in various economic sectors.

▶ **Table 2.7 Percentage of employers in Ontario involved in workplace integrated learning**

Programmes	Percentage
Paid co-ops	41
Student mentoring	38
Apprenticeship	36
Unpaid internship	29
Staff on college advisory committee	33
In class industry projects	22

Source: ICTC, 2016.

Note: Multiple answers were possible and the results were based on a Conference Board of Canada survey of 1,538 Ontario employers in 2013. Therefore, results should be interpreted with caution before extrapolating these findings to all of Ontario.

China

In 2017, the State Council made a decision to strengthen cooperation among industry and universities and vocational training institutions. The objective of that decision was to tackle major structural imbalances between talent supply and industry demand and enhance the contributions of vocational and higher education to economic development and industry.

Internships have increasingly been implemented as a mandatory element of university studies. For example, at Tsinghua University, the curriculum includes internships with companies that last approximately three months in order to help students acquire practical skills. In addition, internships are also considered good recruitment channels (Research mission interview with Tsinghua University, China).

In some cases, post-secondary vocational schools and universities collaborate in order to develop content for specific courses. Shenzhen Polytechnic in China provides three-year training courses developed in cooperation with Huawei, one of the largest ICT companies in China. Students study mathematics in the first year, basic ICT knowledge in the second year and a Huawei-specific training course in the third year. Demonstrating its success, the employment rate among students on the training course is 100 per cent. All graduates of Shenzhen Polytechnic are employed in Huawei or Huawei affiliates (Research mission interview with Shenzhen Polytechnic, China).

Germany

In Germany, six-month internships have been a key building block of study programmes at MUAS. Recently, shorter internships in technology study fields have also been introduced at other research-oriented universities.

In line with this concept of dual VET, dual university programmes have been introduced at certain universities. That study format is very popular among employers, who are obliged to offer positions in their companies for the on-the-job training element of such programmes. Students sign a vocational education contract with a company and given that they must simultaneously combine university study and on-the-job training, it is an intense experience for them. Exam results show that students participating in those programmes are some of the best prepared for employment and are therefore also in high demand by participating companies. Companies offering dual study courses include Siemens and Deutsche Telekom for business informatics, and Volkswagen for computer sciences.

Singapore

As of November 2016, almost 1,600 companies were offering internships to ITE students. At Singapore Polytechnic, internships take place over 22 weeks. To ensure the quality of internships, students write weekly reports and the company supervisor also completes an assessment. Faculty members also meet with the students three times during the internship period (Research mission interview with Singapore Polytechnic. Engineering and science students at NUS in Singapore also undertake six-month internships in a company).

Furthermore, the SSG Work-Study Programme provides opportunities for Singaporeans to pursue a work-study pathway from the diploma to post-graduate degree levels at Institutes of Higher Learning and private educational providers appointed by SSG. Under the SSG Work-Study Programmes, students undertake both classroom study and structured on-the-job training with a company. Every effort is made to ensure that classroom curricula reflect workplace and industry needs.

2.4.5 Government strategies for lifelong learning

Lifelong learning is a concept that covers all education and training during an individual's lifetime, including formal education at school, training courses and adult learning. In many policy contexts, however, lifelong learning has become synonymous with adult education and training (ILO, 2019).

The responsibilities of workers, companies and governmental authorities in terms of providing lifelong learning opportunities vary among the four countries. Training costs tend to be borne by both the individuals receiving training and companies. Furthermore, governments have enacted policies to promote the upskilling and reskilling of workers, although those policies tend to focus on specific groups of individuals or companies.

One particular challenge faced by all four countries is the need to promote upskilling and reskilling for an ageing workforce. For example, electrical engineers may have some good transferable skills that they can use if they retrain as software developers, but it can be a long process that requires trainees to acquire advanced IT-skills and to invest significant time and financial resources, particularly if they enrol in boot camp-style retraining programmes.

Canada

The national Lifelong Learning Plan allows Canadian residents to make withdrawals from their registered retirement savings plans to finance full-time training or education for themselves or for their spouse or common-law partner. In addition, through its 2019 budget, the Government has established the Canada Training Benefit, the key components of which include a new, non-taxable Canada Training Credit to help with the cost of training fees. Eligible workers between the ages of 25 and 64 accumulate a credit balance at a rate of CAD250 (US$187) per year, up to a lifetime limit of CAD5,000 (US$3,745). The credit accumulated can be used to refund up to half the costs of taking a course or enrolling in a training programme. [22]

China

Lifelong learning is one of the guiding principles and strategies of the National Plan for Medium and Long-term Education Reform and Development (2010-2020), which envisages the establishment of a mechanism in which academic credits from continuous education can be accumulated and transferred, in addition to a mechanism for the mutual recognition of qualifications and different types of learning. Pursuant to the National Plan, China also aims to increase the resources earmarked for continuous education in collaboration with educational institutions, research institutions and business enterprises.[23]

Pursuant to the Implementation Plan for Accelerating the Modernization of Education (2018-2022), the Government is facilitating the establishment of a lifelong learning system, formulating relevant laws and regulations on lifelong learning, developing and strengthening collaboration among educational institutions at all levels, encouraging the development of adult education courses, particularly for aged persons, and establishing new educational institutions.[24]

The Plan for Accelerating the Modernization of Education (2018-2022) is complemented by the China Education Modernization 2035 Plan, which provides, inter alia, for the development of a lifelong learning system for all citizens, and the establishment of a national qualifications framework, a cross-department and industry-wide coordination mechanism and a professional support system. China Education

22 Exchange rate calculated on 7 August 2020.
23 Outline of China's National Plan for Medium and Long-term Education Reform and Development (2010-2020), Beijing, 20 June 2010. Available at: ncee.org/wp-content/uploads/2016/12/Sha-non-AV-5-China-Education-Plan-2010-2020.pdf (accessed on 29 July 2020).
24 Xinhua News Agency, "The General Office of the Central Committee of the Communist Party of China and the General Office of the State Council has issued the Implementation Plan for Accelerating the Promotion of Education Modernization (2018-2022)", 23 February 2019. Available at: www.gov.cn/zhengce/2019-02/23/content_5367988.htm. (accessed on 29 July 2020).

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Modernization 2035 also provides for the establishment and strengthening of national credit banking and learning achievement certification systems. Vocational schools and higher education institutions are also encouraged to develop continuous training courses for company employees.[25]

Furthermore, in a decision issued in April 2018, the State Council called for the establishment of a lifelong professional skills training system and for workers to enjoy equitable access to skills training throughout their careers. In its decision, the State Council also emphasised that business enterprises needed to play a crucial role in providing large-scale training to employees, and called for the strengthening of certificate programmes and for further resources to be allocated to government-subsidized training programmes.

Germany

For many years, the Government of Germany has provided upskilling for the unemployed and, pursuant to the adoption of a new law for the improvement of labour market integration in April 2012, has introduced a voucher system for vocational training for those seeking employment. A job counsellor at the unemployed worker's local employment agency decides whether the worker could benefit from ICT training or even retraining in ICT and, if this is the case, issues a voucher to cover training fees. Courses can be chosen from the KURSNET database, which lists thousands of courses offered by certified training institutions.

The Federal Government has adopted a national continuous training strategy (BMBF, 2019) with the aim, inter alia, of promoting transparency in continuous training, improving the quality of continuous training guidance provided to individuals and companies, and more clearly defining the responsibilities of employers' and workers' organizations.

Singapore

The Government of Singapore is investing substantial resources in continuous education and training (Research mission interview with Institute for Adult Learning, Singapore). The main initiative for sector-specific training is TeSA, an umbrella organization that was established by IMDA in partnership with strategic partners, including WSG, SSG and stakeholders from industry. TeSA offers a range of programmes to current ICT professionals and professionals in other fields to help them upgrade and acquire new skills in line with current market needs (see box 2.7).

▶ Box 2.7 Techskills Accelerator programmes in Singapore

Key programmes offered by TeSA in Singapore include the following:

a. Company Led Training Programme

An initiative that aims to accelerate professional development through on-the-job training for new to mid-senior level professionals. Programme participants acquire the skills needed by industry, particularly those that support digital economy transformation.

b. Critical Infocomm Technology Resource Programme Plus

A programme to help ICT workers keep abreast with technological change by providing them with continuous technical skills training.

c. Tech Immersion and Placement Programme

A programme designed for non-ICT professionals, especially graduates in STEM subjects, with a view to transforming them into industry-ready ICT professionals. Programme participants received immersive training and mentorship support from stakeholders in industry and are then placed in professional tech positions in companies.

d. Singapore's Professional Conversion Programmes

Designed to help experienced workers move into high-demand industries, Professional Conversion Programmes provide industry professionals, managers, and executives with skills training to help them change career and obtain jobs in a new field. Several Professional Conversion Programmes, including the Professional Conversion Programme for Data Analysts and the Professional Conversion Programme for Full Stack Software Developers, place particular emphasis on ICT skills. Participants in a Professional Conversion Programme receive up to 90 per cent of their monthly salary and assistance with course fees.

Source: IMDA and WSG.

25 Xinhua News Agency, "The Central Committee of the Communist Party of China and the State Council has issued "China Education Modernization 2035", 23 February 2019.

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3

The international migration of ICT specialists

3.1 Overview of migration trends

Respecting the rights of migrant workers and families and ensuring that international labour standards are upheld are crucial in the management of labour migration. The Global Compact for Safe, Orderly and Regular Migration covers all aspects of international migration, including labour migration. Additionally, the Migration for Employment Convention (Revised), 1949 (No. 97) and Migration for Employment Recommendation (Revised), 1949 (No. 86) along with the Migrant Workers (Supplementary Provisions) Convention, 1975 (No. 143) and Migrant Workers Recommendation, 1975 (No. 151) contain provisions to ensure that migrant workers are offered basic protections.

Those Conventions outline several measures that member States should undertake to protect the rights of migrant workers. They state that migrant workers should not be treated less favourably than nationals regarding remuneration, collective bargaining, accommodation and access to social security benefits.

Canada, Germany and Singapore have a long history of immigration and have had positive net migration balances during recent years. According to United Nations data, between 2010 and 2015, net migration, that is to say the number of immigrants minus the number of emigrants per 1,000 inhabitants, was +11.8 in Singapore, +7.1 in Canada and +4.8 in Germany, compared to -0.2 in China.

Forecasts for the period 2015 to 2020 estimate lower net migration to Singapore (+4.7). Increased refugee inflows have resulted in higher net migration to Germany (+6.6). Forecasts for Canada show a lower net migration rate of 6.5. That figure could be driven higher, however, by the Government's recently adopted plan to increase annual immigration to Canada to nearly 1 per cent of the total population by 2021.[1] On the other hand, the net migration balance in China is expected to remain slightly negative. An overview of net migration in the four countries is shown in figure 3.1 next page.

The comparability of national statistics is limited by the fact that national statistics differ as to the migrant status they report on. In Germany, for example, figures are disaggregated by nationality and by "migration background" – a person is deemed to have a migrant background if he or she, or at least one parent, did not acquire German citizenship at birth (Destatis, 2019c). On the other hand, in Singapore, a distinction is made by residency status.

Canada

Canada was the first OECD country to establish a national skilled labour migration system (OECD 2019d). Compared to other OECD countries, Canada's foreign-born population has the highest level of education, and approximately 60 per cent of the foreign-born population in Canada has at least a tertiary education qualification.

1 For further information, see: www.canada.ca/en/immigration-refugees-citizenship/news/notices/supplementary-immigration-levels-2019.html

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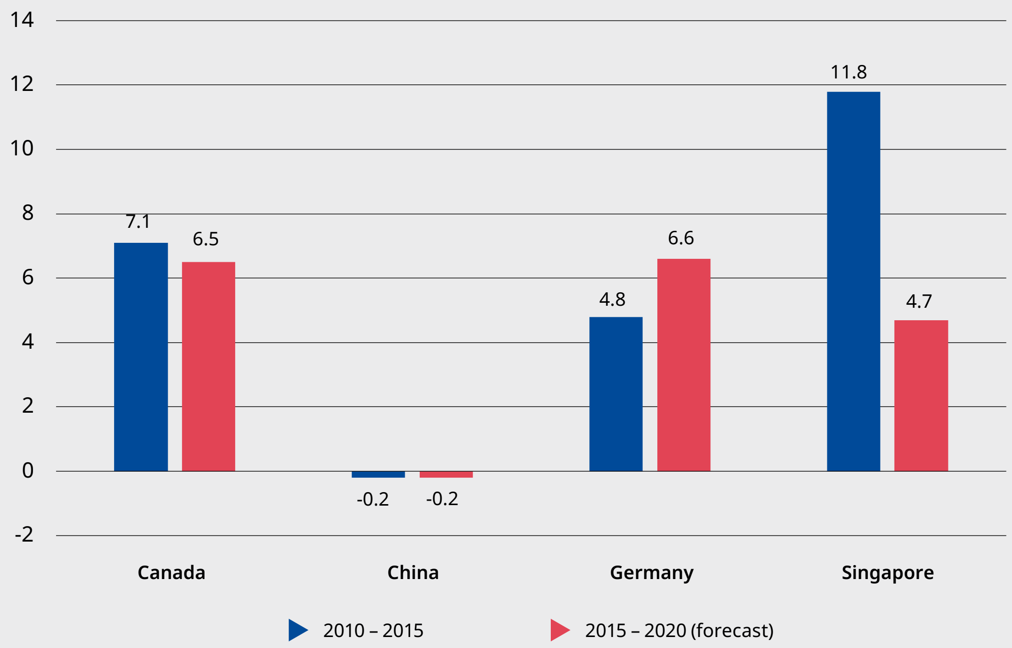
▶ Figure 3.1 Net migration for the period 2010-2015 and net migration forecasts for 2015-2020 (per 1,000 inhabitants)



Source: Population Division, United Nations Department of Economic and Social Affairs

Canada is becoming an increasingly popular destination country for migrants. In 2017, for example, while Indian immigration to the United States declined by 7 per cent, migration flows from India to Canada increased sharply by more than 30 per cent: a clear indication that migration flows have been diverted from the United States to other English-speaking countries (OECD 2019e).

China

China, along with India, is one of the major origin countries for migration to OECD countries. Flows from China to OECD countries averaged 520,000 per year between 2007 and 2016 and increased by 13 per cent to Canada and by 6 per cent to Japan over that period. Overall migration flows rose by almost 3 per cent, despite decreasing flows to the United States and the Republic of Korea (OECD 2019e).

Germany

In previous decades, immigrants to Germany were mainly found in low-skilled occupations. Migration of highly-skilled workers to Germany has been on the rise since the 1990s, however. A peak was reached in 2010, with about 47 per cent of new immigrants holding a university-level degree (Seibert and Wapler, 2020).

Singapore

In 2015, 212,000 Singaporeans were reported to be living overseas, compared with 157,800 in 2004, marking an increase of more than a third in just over a decade. Singaporeans overseas now account for some 6 per cent of the country's population (Today, 2015).

3.1.1 International labour migration of ICT specialists

In Canada, Germany and Singapore, immigration of ICT specialists has been sizeable in recent years. Comparable data for China is not publicly available, but research mission interviews suggest that it remains low.

Canada

Of the four countries, Canada has the highest levels of immigration of ICT specialists. In October 2019, approximately 40 per cent of employed ICT specialists were born outside Canada, compared to 32 per cent of those employed across all occupations in the country (ICTC, 2019). The number of immigrants working as

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ICT professionals increased by 6 per cent between 2017 and 2018.

According to the 2016 Census of Population, the ICT occupations with the highest percentage of foreign-born workers were electronics assemblers, fabricators, inspectors and testers (58 per cent), software engineers and designers (52 per cent), computer engineers (excluding software engineers and designers) (48 per cent), electrical and electronics engineers (47 per cent), and information systems testing technicians (47 per cent). In particular, immigrants from India and China are often employed in ICT occupations.

China

The share of foreigners in employment remains low in China. According to Miao and Wang (2017), there were 612,000 foreign experts working in China in 2013. The ratio of foreign national to Chinese national workers in the labour force is estimated to be only 0.09 per cent, much lower than in Germany, Singapore and Canada. The immigration of highly-skilled workers to China is often linked to foreign direct investments in Chinese business enterprises (ILO and IOM, 2017).

Germany

In Germany, among workers with a contract of employment in 2018, only 10 per cent of core ICT specialists did not hold German nationality: that figure is lower than the proportion of non-German nationals across all occupations (12 per cent) (BA, 2019). The number of foreign ICT specialists has recently been on the rise and, between 2017 and 2018, the number of foreign ICT-specialists increased by 17 per cent, whereas the total number of ICT specialists increased by only 5 per cent.

Sector employment data from Germany shows noticeable variations in the proportion of non-German workers in various ICT subsectors: it remains above average in software publishing (16.4 per cent) and information service activities (14.2 per cent), average in computer programming and consultancy (10.2 per cent), and below average in ICT manufacturing (8.2 per cent) and telecommunications (8 per cent).

Singapore

As is the case in Canada, immigrants comprise a significant proportion of the workforce in Singapore. The share of immigrants among ICT specialists has increased in Singapore from 26 per cent in 2013 to 29 per cent in 2018 (IMDA, 2014-2019). Despite that increase, the proportion immigrants working as ICT specialists is no higher than the proportion of immigrants working in other professions, namely 30.6 per cent (this figure includes immigrants who are categorized as "non-resident" but does not include domestic workers from outside the country).

Countries of origin

Numerous factors, including geographical proximity, cultural affinities, language skills, a tradition of migration and economic ties among countries influence both the choice of destination country by potential migrants and the recruitment strategies adopted by companies. A number of other incentives and barriers to migration are discussed in section 3.2 below. A scarcity of specific skills has also led to the employment of specialists from non-traditional countries of origin, such as the employment of Indian and Chinese ICT specialists in Germany.

Geographical proximity is a key factor that has fostered migration flows of ICT specialists towards Germany and Singapore.

In the case of Germany, ICT specialists are mainly recruited from EU member States because of the unrestricted movement of labour and strong economic ties among EU countries, and from non-EU countries with a long-established tradition of migration, such as Turkey. As of June 2018, 41 per cent of foreign ICT-specialists working in Germany were from EU States, and especially from Bulgaria, Croatia and Romania (6,000 specialists). Many of those workers were also motivated to relocate to Germany because of significant wage differentials. Another source of migrant labour was Italy (4,000 specialists). The remaining 59 per cent were from countries outside the EU, including India (11,000), the Russian Federation (4,000) and Turkey (4,000). Some 4,000 ICT specialists were asylum seekers. Those statistics are illustrated in figure 3.2.

Indian and Chinese nationals working in Germany have typically been educated in STEM subjects. In contrast, migrants to Germany from other countries have studied a much broader range of subjects (IW, 2018).

In Singapore, a survey of 200 ICT specialists conducted by TalentKraft, an HR consultancy firm, revealed that most foreign ICT specialists are from South and South-East Asia: 37 per cent are Indian, 21 per cent Filipino, 13 per cent Malaysian, 9 per cent Indonesian and 14 per cent are from other countries. (TalentKraft, n.d.).

In Canada, most foreign ICT specialists are from Asian or European countries. In 2011, 21 per cent of ICT specialists in Canada were Chinese, 14 per cent were South Asian and 4 per cent were Filipino; 19 per cent of ICT specialists were from EU countries (ICTC, 2016). Canada does not attract many ICT specialists from the United States, where there are numerous highly paid ICT jobs.

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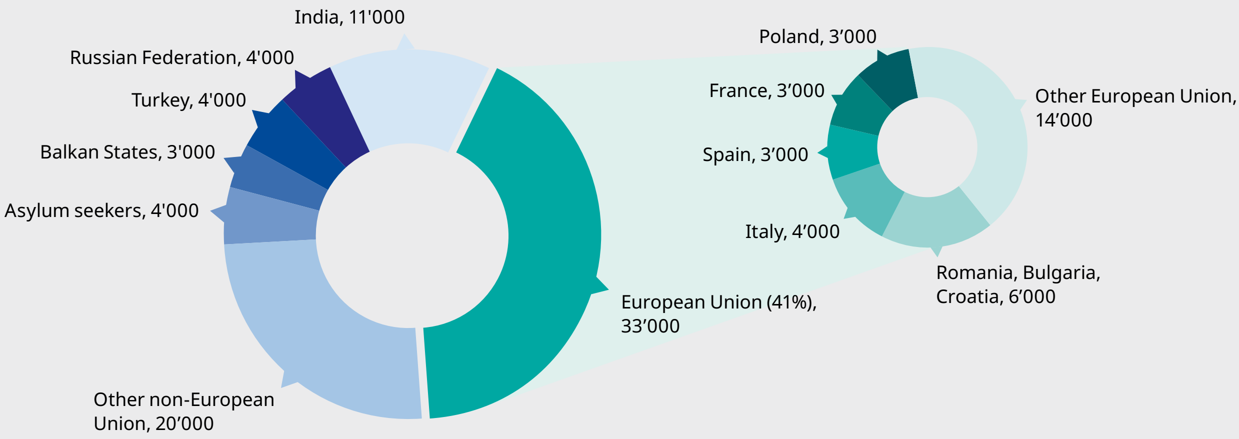
▶ **Figure 3.2 EU and non-EU immigrants working as ICT specialists in Germany, 2018**



Source: BA, 2019

3.1.2 Migration channels and recruitment strategies

The international migration of ICT specialists to Canada, China, Germany and Singapore has increased in recent years as a result of high labour demand and skills shortages. Labour migration takes place through a number of channels, and companies use a variety of recruitment strategies to fill vacancies while complying with visa regulations.

Recruitment of workers from abroad: companies, recruiters and public employment agencies (in the case of Germany, for example) reach out to potential candidates in countries of origin. In the case of China, the greatest potential for immigration lies with the large number of Chinese students and skilled workers living abroad (ILO and IOM, 2017), and a number of Chinese employers are now actively reaching out to those individuals to try to fill work vacancies.

Recruitment of immigrants already in the destination country: this includes the recruitment of recent immigrants and those who have been in the destination country for a considerable period of time. In Canada, for example, immigration is not always linked to having a job offer, and companies may be able to recruit migrants who have obtained permanent residency in Canada (those individuals were previously referred to as “landed immigrants”). According to a study conducted in 2016, only 4 per cent of immigrants working in ICT positions in Canada were temporary contract workers (Cameron and Faisal, 2016).

Transfer of individuals employed by multinational companies: employees may be offered the opportunity to work at a site or a subsidiary of their company in another country, usually on a temporary basis, within the context of their career paths. For example, the headquarters of the German semiconductor company Infineon employs workers from more than 60 countries, many of whom are transferred from Infineon offices and plants outside Germany (Research mission interview with Infineon, Germany).

There are two main reasons why employers recruit from abroad or employ immigrants already in the country: first, to overcome skills shortages, and secondly, for some employers, to save labour costs. Many employers prefer to employ immigrants who are already in the country and already have relevant work experience because of the high costs and significant risks associated with recruiting employees from abroad. Certain employers may seek to recruit ICT specialists from abroad due to their lower salary expectations (Research mission interviews with Modis, a recruitment agency, and Scout24, a digital marketplace company, Germany).

3.1.3 Migration of students

The migration of students is a key path for accessing a country’s labour market as it facilitates access to internships during studies, equips students with a formal education that employers can easily identify and trust, and gives students in-depth knowledge of how a country’s labour market functions. However, obtaining employment in the destination country is not the only reason individuals choose to study outside their home countries. Students may also migrate to take advantage of higher-quality educational courses than those available in their home countries or to pursue studies in specialized fields, in particular at master's and doctorate levels. They may also wish to gain international experience in order to improve their chances of securing well-paid employment upon their return to their home countries.

The choice of country in which to study depends on a number of factors, including the reputation of universities and the quality of education offered, the availability of courses taught in English, the fees students must pay for tuition, labour market prospects for graduates, and the ease with which individuals can obtain work permits while studying and upon graduation.

Canada

According to the 2016 Census of Population, 43 per cent of all immigrants in the ICT sector studied in Canada, and of all immigrants with a post-secondary education working in the ICT sector, 48 per cent studied in Canada. This suggests that many ICT workers were international students who received employment offers in Canada following the completion of their studies. International students comprise 13 per cent of the total tertiary student population, despite the fact that they usually pay higher tuition fees than national students. A third of doctorate level students were international students (OECD 2019f).

China

Whereas Canada and Germany have long been destination countries for international students, China remains a country of origin. In 2014, there were 1,088,900 Chinese overseas students and that figure has continued to increase in recent years. Most Chinese students chose to study in Australia, Canada, Japan, New Zealand, the United States and the United Kingdom (Miao and Wang, 2017).

In 2013, of the 353,500 Chinese who studied overseas before returning to their home country,[2] 60 per cent had obtained a master's degree, 30 per cent a bachelor's degree, and 6 per cent a doctorate (ILO and IOM, 2017).

While still relatively low, the number of foreign students enrolled in courses in China has grown significantly in the last decade (ILO and IOM, 2017). In 2015, there were 398,000 international students in China, the majority of whom neighbouring countries. However, increasing numbers of foreign students also come from countries with which China has close economic ties, including France, Germany and the United States (Miao and Wang, 2017).

Germany

In 2017, 8 per cent of students in Germany were foreign nationals, including second and third generation foreign nationals who were born in Germany (OECD, 2019g). The proportion of foreign students was lowest at bachelor's level (5 per cent), followed by doctorate level (10 per cent), and highest at master's level (14 per cent). This shows that most international students in Germany wish to obtain higher-level degrees, perhaps because few high-quality master's courses are offered in certain countries of origin, and because a higher proportion of master's courses in Germany are taught in English as compared to bachelor's degree courses. Among international students, Chinese students comprised the largest group (11 per cent), followed by Turkish students, many of whom were second or third generation migrants, and Indian nationals (Destatis, 2019a). Other major groups come from other EU countries, the Russian Federation, Ukraine and countries in the Middle East and North Africa.

In ICT study fields, however, one sixth of students were foreign nationals in the 2017-18 winter semester: double the figure for most study courses. Courses with the highest proportions of foreigners included computer and communication technologies, engineering and technical informatics, medical informatics, and bioinformatics. Non-German students who receive their university entrance qualification outside Germany tend to enrol in STEM courses (Apolinarski and Brandt, 2019).

Singapore

Most foreign students at Singaporean universities are from other Asian countries. The proportion of foreigners is very high at the doctorate level. At NUS, about 70 per cent of PhD students and researchers are foreigners.

Gaining international experience during tertiary education has become increasingly important for students' career development; some 70 per cent of NUS students will study overseas at one of 300 partner universities, for example (Research mission interview with NUS, Singapore). In 2015, about 30 per cent of Singaporeans studying abroad were enrolled in a master's or doctoral programme (Asian Development Bank Institute (ADBI), ILO and OECD, 2018).

2 It should be noted, however, that the overwhelming majority of returnees would not be able to meet the standards set for the Thousand Talents and Ten Thousand Talents programmes (ILO and IOM, 2017).

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3.2 Incentives and barriers to labour migration

The migration of skilled labour is driven, primarily, by employment conditions, future career prospects, and potential living conditions, and the key factor influencing labour migration is the gap between perceived benefits in the country of origin and in the country of destination. Such benefits include differences in employment opportunities and income. However, those wishing to migrate may also consider factors such as access to high-quality health care and education or the quality of life they expect to enjoy, including their access to nature and to cultural opportunities. Potential migrants will carefully consider the potential benefits of migration against any potential disadvantages and costs (Tuccio, 2019). Box 3.1 summarizes the incentives and barriers to the migration of ICT specialists. These are further discussed below.

3.2.1 Migration incentives

Incentives for labour migration can be grouped into push and pull factors. While push factors relate mainly to the political, societal and economic situation of the country of origin, pull factors refer to the situation in the destination country. Furthermore, a distinction may be drawn between pecuniary (mainly earnings and taxes) and non-pecuniary factors and amenities, both of which can influence the decision to relocate and the choice of destination country. Non-pecuniary amenities encompass, in particular, the skills environment, inclusiveness, quality of life, and the environment for families (Tuccio, 2019). A country's attractiveness as compared to another potential destination country also depends on the visa regulations and other regulations in place that affect labour market access. Figure 3.3 provides an overview of the factors that can

Box 3.1 Incentives and barriers to migration

Incentives and barriers to the migration of ICT specialists include the following:

Incentives:

Wage differentials, well-developed welfare systems, access to good healthcare and education services, cultural and geographic proximity, an enabling environment for entrepreneurs, a vibrant start-up scene, opportunities to work for large and renowned firms, and a high quality of life.

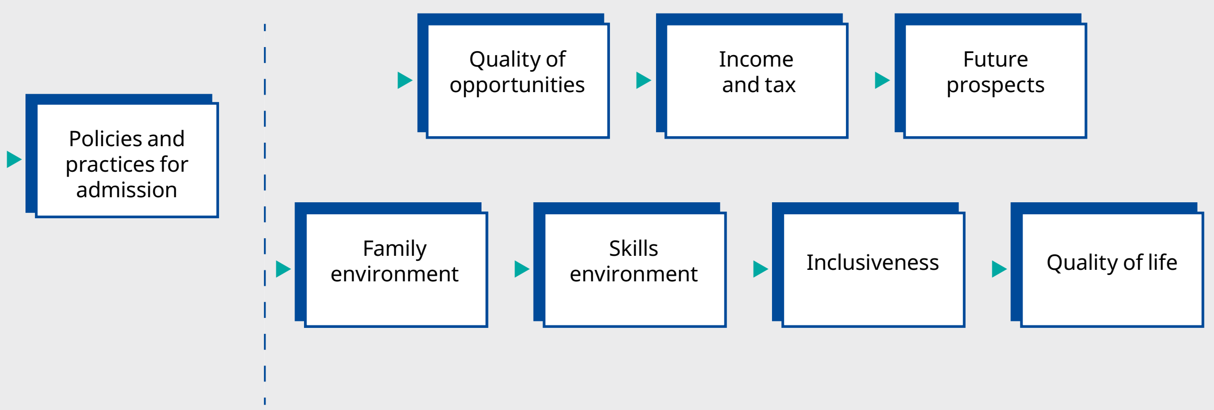
Barriers:

Strict visa regulations, including strict visa policies for family reunification, a failure to recognize foreign qualifications, and restrictive national regulations on specific occupations (for example, engineers in Canada often require additional certification in order to practice their professions).

Incentive and a barrier:

Language skills were identified as both an incentive and a barrier to migration

Figure 3.3 Factors that can influence potential migrants' relocation decisions



Source: OECD and Tuccio, 2019

influence a potential migrant's decision to relocate to another country.

Several organizations have attempted to measure the attractiveness of countries for skilled and highly-skilled migrants. To that end, the OECD Indicators of Talent Attractiveness draw on group-specific observations from large-scale household surveys and immigration data that capture the difficulties that migrant face, including when trying to obtain visas or residence permits. The OECD Indicators place migrants into three categories, namely very highly-skilled migrants with master's or doctoral degrees, migrant entrepreneurs, and international students, and measure talent attractiveness in seven dimensions. These include: quality of opportunities; income and tax; future prospects; family environment; skills environment; inclusiveness; and quality of life (Tuccio, 2019).

According to the OECD Indicators of Talent Attractiveness, Canada ranks fifth (behind only Australia, Sweden, Switzerland and New Zealand, in that order) and Germany ranks twelfth among 35 OECD member countries in terms of their attractiveness for potential migrant workers with master's or doctoral degrees. Canada is ranked first in terms of its attractiveness for migrant entrepreneurs, while Germany ranks sixth. Germany ranks third in terms of its attractiveness for students. That high ranking is mainly due to the high quality of training provided by German educational institutions and the country's low tuition fees, while Canada ranks eighth out of the 35 countries.

The INSEAD Global Talent Competitiveness Index also considers skills development and is based on the "Attract-Grow-Retain" framework for talent management that has been implemented by several large multinational companies. In the 2019 Global Talent Competitiveness Index, Singapore was ranked second (after Switzerland), Germany was ranked fourteenth, Canada fifteenth and China forty-fifth out of 125 countries. When looking only at the "Attract" pillar of the Index, Singapore ranked first, Canada seventh, Germany twentieth and China seventy-sixth (INSEAD, 2019).

Research mission interviews conducted in the context of this study provided invaluable insights into specific incentives for the migration of ICT specialists. Key reasons why ICT specialists migrate to Canada include perceived inclusive public policies, the widespread use of the English language, an enabling environment for entrepreneurial communities and start-ups, and access to venture capital and public funding grants (Teja, 2018). Furthermore, a number of ICT specialists from Europe cited the Canadian lifestyle and easy access to nature as significant factors that had encouraged them to relocate (Research mission interview with Modis, Canada).

A number of private sector companies have reported that the main incentives for ICT specialists to migrate to Germany are of an economic nature. These include the country's robust labour market, and interesting employment opportunities in large, well-known companies. However, the well-developed welfare system and the good health and education systems are also perceived as particularly important (Research mission interviews with Modis and with Scout24, Germany). Immigrants from Eastern European countries also choose to relocate to Germany due to cultural proximity issues and because they often already speak some German (Research mission interview with Scout24, Germany).

A survey of highly-skilled Indian migrants and international students in Germany also revealed that some Indian female migrants in Germany perceived emigration as an opportunity to distance themselves from patriarchal structures in India. Such a perception might also motivate female migrants to relocate to other countries.

According to a large recruitment agency in Singapore, migrant ICT professionals often state that they are attracted by the country's infrastructure, geographical location, relatively low income taxes, high standard of living and safety, in addition to the widespread use of the English language (Research mission interview with EMA Partners, Singapore).

3.2.2 Migration barriers

Language

Language is an important factor that helps determine migration flows. Migrants' language skills also help determine whether they will find appropriate employment in their destination countries. Indeed, it has been shown that migrants' earning potential is often related to their capacity to communicate in the local language of their destination countries. A study conducted by IZA in 2012 also found that migrants are more likely to learn the language of the destination country if it is closely related to a language that they already know.

A good command of English and knowledge of the destination country's language (if different from English) are key requirements for migrant ICT workers. Thus, even if they have excellent technical skills, deficits in language skills may significantly reduce migrants' ability to find adequate employment and undermine their prospects for career development. According to research mission interviews, migrants to Canada are expected to have high-level English language skills and additional French language skills may be a requirement for civil service positions and jobs in the province of Québec (Research mission interviews with Modis and Semios, Canada).

In Germany, there is as yet no consensus as to the level of German language skills that migrants should acquire. Several large multinational companies and many smaller German companies use English as a working language alongside German, at least in some departments. This is the case, for example, in the research department at Infineon, a semiconductor company. However, this is not the case for the majority of companies in Germany, where a good command of German is often essential, particularly in positions that require employees to communicate with German customers.[3] Furthermore, according to the results of survey on recruitment challenges in Germany, some 22 per cent of employers complained that the German language skills of candidates for job positions were often poor (Bitkom, 2019b).

Companies that post job openings on international platforms such as LinkedIn reported that they receive many applications from abroad, in particular from India and other Asian countries. However, due to German language requirements, many of those applicants cannot be placed in Germany. According to Bitkom, German language skills are not crucial for many ICT occupations. That is particularly the case in programming jobs. There is, however, a widely-shared view that German language skills are important because they facilitate the integration of migrants into German society. Limited access to German language courses may therefore significantly undermine the employability of foreign ICT specialists (Research mission interview with ZAV, Germany). To improve foreign workers' language skills, some employers, including AKDB, offer German language courses to their employees.

Language barriers can seriously impede the employability of foreign ICT specialists in China. English is not widely spoken or understood in most Chinese companies and Mandarin is a difficult language to learn for many foreigners, who must often invest considerable time and financial resources in language programmes in order to gain a degree of proficiency in the language. As a consequence, many companies, including iDreamSky, a gaming company, are reluctant to employ foreign ICT specialists, despite the skills shortages and recruitment challenges they often face. Conversely, inadequate language skills can prevent Chinese university graduates from finding employment abroad (Research mission interview with Tsinghua University, China).

Institutional barriers

Access to the labour market is usually regulated by migration policies. Migrants' chances of successfully accessing the labour market will depend on the visa regime in place, their formal educational qualifications, their language skills, whether they have been offered a formal employment contract, and labour market needs. Visa applications can be expensive and take considerable time to process. Those costs and processing times may deter individuals from applying for visas and deter companies from recruiting from abroad. Relocation also entails other costs for employees and employers, including settlement costs, and fees for international schools for migrants' children. Employers therefore usually prefer to recruit migrant ICT workers who are already in the country (Research mission interviews with Modis and Radical IO, a private sector ICT company, Canada).

Family reunification and work permit regulations for accompanying partners are also an important factor (Research mission interviews with IAB, Germany and with Semios, Canada). In China, a lack of mutual recognition of social insurance and technical certification can impede efforts to recruit skilled workers from abroad (Research mission interview with CEC/CEDA, China). International migrants in China face numerous other challenges, including in connection with bureaucratic immigration procedures, obtaining permanent residency, the lack of support offered to migrants' families, social security contributions and regulations that impede students from taking up employment once they have completed their studies (ILO and IOM, 2017; Miao and Wang, 2017).

Although many employers repeatedly state that formal qualifications are less important for ICT specialists than specific skills (often acquired through work experience rather than through the formal education system), formal qualifications are often required for a visa to be issued, at least in Canada and Germany. In Germany, Bitkom has been pressing lawmakers to relax visa regulations in order to address that issue (Research mission interview with Bitkom, Germany).

In Canada, an engineering degree issued abroad must be recognized as equivalent to a Canadian qualification before the degree holder can take up employment as an engineer: it is not sufficient merely to demonstrate that a tertiary education level degree course was completed. As a result, it is extremely difficult to obtain authorization to hire an engineer from abroad, even

3 Information provided by Hays, a recruitment agency, Germany.

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if he or she has strong ICT skills. Furthermore, many companies are reluctant to trust formal educational qualifications obtained abroad, thereby making it even more difficult for recent migrants to find employment. Canadian employers do, however, tend to value any work experience that a migrant has obtained in Canada.

3.2.3 Return migration: China and Singapore

China

A survey conducted among STEM faculty members in the 25 highest ranked universities in China revealed that 17 per cent of faculty members had obtained their most recent degree abroad (Han and Appelbaum, 2018).[4] Of those who had obtained a degree from an educational institution outside the country, 38 per cent had studied in the United States, 20 per cent in Japan and 7.4 per cent in Germany. Of those who had obtained a doctorate level degree abroad, 82 per cent had initially remained in the destination country to work while 18 per cent had returned immediately to China upon graduation. Moreover, 19 per cent of respondents currently held faculty positions at both an institution in China and an institution abroad. Some 80 per cent of respondents who had studied abroad had made the decision to return to China within 7 years of obtaining their foreign degree.[5]

Returnees who studied abroad indicated that they chose to do so because it provided them with the opportunity to conduct higher quality research in their field (78 per cent); to obtain a higher quality education (69 per cent); to experience living abroad (60 per cent); to have the ability to conduct more innovative research (41 per cent); and to improve their future career prospects (33 per cent).[6] Proximity to friends and family, and other reasons were cited by less than 10 per cent of respondents, indicating that network migration does not play an important role. The results may not fully reflect the situation of all Chinese students who pursue STEM studies abroad, as most survey respondents had planned to return to China to continue their career paths.

The same survey revealed that, for those who had obtained master's and/or doctorate degrees abroad, the decision to return to China was based, primarily, on labour market trends in China. Those individuals had expected to enjoy better job opportunities in China (46 per cent) and take advantage of strong professional networks (22 per cent). Approximately four-fifths of both returnees and scholars who had not studied abroad acknowledged that obtaining a foreign degree provided individuals with certain advantages in China. Both groups agreed that a foreign degree was prestigious and that individuals who studied abroad were likely to obtain a better education and more in-depth knowledge of their field of study.

Family-related reasons were also cited, but were viewed as less important than career development considerations: some 18 per cent of respondents cited "wanting their children to receive a Chinese education" as a reason to return to China, while 17 per cent saw "more job opportunities for their families in China", and 14 per cent said their decision to return to China was due to other personal reasons. Challenges related to social integration abroad or to visa requirements were mentioned by less than 10 per cent of respondents who had studied overseas.[7]

Chinese nationals are often keen to return to China if they receive an attractive job offer. Some Chinese companies facing recruitment challenges are particularly interested in hiring Chinese ICT specialists employed abroad. Zhaopin Ltd., one of the largest recruitment agencies in China, also contacts Chinese students studying abroad to make them aware of job offers in China, as their experience abroad and their adaptability are seen as particularly advantageous in the rapidly changing ICT industry (Research mission interview with Zhaopin Ltd., China). In order to attract highly-skilled ICT specialists, companies often offer high salaries and good employee benefits, including bonus and stock options. For TAOLE, a gaming company with 220 employees, work experience abroad is not a job requirement, but employees who have studied or worked overseas are preferred to those who have not, as the former tend to have good communication skills and are better able to adapt to changing job requirements (Research mission interview with TAOLE, China).

Singapore

According to a survey conducted in 2018, although 85 per cent of Singaporeans want to try living overseas, only 15 per cent want to migrate for good

4 In total, 731 responses to the survey were received. The response rate was low, however.
5 Of the 96 individuals who had received their most recent degree from a foreign educational institution but who did not hold dual faculty positions in China and abroad, 60 per cent had returned to China within the preceding 5 years, 19 per cent had returned within the preceding 5 to 7 years, 10 per cent had returned within the preceding 8 to 10 years, and 10 per cent had returned after 10 years or more abroad.
6 Percentages do not add up to 100 per cent as respondents were allowed to select all the reasons why they had chosen to study abroad.
7 Relevant figures were as follows: did not adjust well to foreign culture (9.9 per cent); required to return to China upon graduation (5.8 per cent); unable to obtain a visa/sponsorship to stay in host country (3.3 per cent), and; did not want to work in a foreign institution of higher education (2.5 per cent).

(Singapore Business Review, 2018). Those figures suggest that return migration rates to Singapore is likely to remain high. Overall, Singaporeans living overseas often express the desire to return to their home country later in their lives and, among the many overseas Singaporeans interviewed in the course of this research, most said that they felt a sense of belonging to Singapore, and a commitment towards their families and country.

Some Singaporean ICT specialists might be reluctant to return, however, because of the career opportunities elsewhere. Highly-skilled specialists often wish to be involved in exciting and demanding projects, and opportunities for such projects are to be found in many other parts of the world (Research mission interview with EMA Partners, Singapore).

According to a study conducted by the Institute for Policy Studies at NUS, the number of Singaporeans working overseas increased by 24 per cent between 2007 and 2016, from 172,000 to 213,400, respectively (Yong, 2017). Research conducted by SGTech on Singaporeans working overseas indicates that concerns about living and working conditions in Singapore also discourage them from returning to their home country. Indeed, achieving a good work-life balance is a key concern for Singaporeans. Other common concerns include the high cost of living in Singapore and a lack of support that would facilitate their return, such as assistance to help them find employment, schools and housing.[8]

However, if living standards were higher in Singapore compared to Singaporean migrants' destination countries, migrants would be more willing to return home, or would choose to commute rather than relocate permanently (Research mission interview with SGTech, Singapore).

According to a 2018 report by KPMG, 59 per cent of multinational tech companies with a presence in Asia have their regional headquarters in Singapore. That fact could, potentially, motivate many Singaporean ICT specialists concerned about their career prospects to return from posts overseas.

Government agencies in Singapore have increased their outreach efforts in recent years to encourage expatriate Singaporeans to take up employment in their home country. To that end, the Singapore Global Network, a division of the Economic Development Board (EDB), has supported initiatives to bring Singaporeans together, including the inaugural Singapore Community Day in San Francisco in the United States, the Singapore Speakers' Series, and annual Singapore Day celebrations.

Singaporean citizens residing outside Singapore are now eligible to participate in the Tech Immersion Placement Programme. Furthermore, IMDA reimburses course fees paid by overseas participants in the Programme upon receiving proof that they have completed job placements in Singapore within 12 months from the training completion.

▶ 3.3 Systems and policies relevant to the international labour migration of ICT specialists

3.3.1 Immigration policies and visa regulations

Canada

The Constitution of Canada enshrines labour migration as a shared responsibility between the federal Government and provincial governments. At the federal level, migration in Canada, including the administration of work permits, is managed by IRCC, which uses a points-based federal selection system. Work permits that require a 'Labour Market Impact Assessment' are administered in cooperation with ESDC. Provinces have their own specific rules regarding migration and the integration of migrants into society.

A points-based system is used for permanent skilled labour migration to Canada. That system, which was introduced in 1967, has been updated on several occasions to reflect changes in the country's approach to migration management and changes in political priorities. The Government adjusts selection criteria by assigning more or fewer points to certain factors. Following the entry into force of the Immigration and Refugee Protection Act in 2002, human capital factors such as education, work experience and language skills have been given more weight.

8 Data from SGTech overseas Singapore Tech Worker research.

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In June 2017, the Government of Canada launched the Global Skills Strategy to provide faster and more predictable access to top global talent. Under the Strategy, companies make commitments to increase investments, bring new skills to Canada and create more Canadian jobs. There are four components of the Global Skills Strategy that relate to temporary foreign workers, one of which is the Global Talent Stream of the Temporary Foreign Worker Program. The Global Talent Stream, through which Canada seeks to attract highly-skilled individuals to work in the country's tech industry by fast tracking work permit approvals. Indeed, under the Global Talent Stream, the federal Government can issue work permits for individuals in less than two weeks. More than 1,000 Canadian companies have used the Global Talent Stream to hire more than 4,000 highly-skilled foreign workers to address short-term skills needs. According to ESDC, the Global Talent Stream has received very positive feedback from employers and applicants and was made permanent in March 2019. Since then, recruiters for Canadian high-tech companies have noted a surge of interest from foreign high-tech workers.

In 2018, roughly half of all permanent economic immigrants were selected by provincial governments. The British Columbia Ministry of Jobs, Trade and Technology is responsible for establishing British Columbia as a hub for tech companies and attracting suitably qualified talent. In support of those priorities, they launched a pilot under the British Columbia Provincial Nominee Program, which seeks to ensure that the technology sector can attract and retain the talent it needs. Provincial Nominee Program staff work with local tech employers to address their talent needs by providing a fast track, permanent immigration pathway for in-demand foreign workers and international students.

China

In 2004, China introduced a "Green Card" system, allowing foreigners to apply for permanent residence in the country. However, it remains very difficult for applicants to satisfy all the requirements for permanent residence and, consequently, only 7,300 of the 600,000 foreigners living in China had been issued a Green Card by 2013 (ILO and IOM 2017; Zhang and Zhou, 2016). As of mid-2019, the Chinese immigration authorities had issued some 133,000 visas and residence permits to foreign entrepreneurs, investors and technical specialists since 2015 (Zekun, 2019).

In 2015, two work visa mechanisms, namely the Employment Permit for Foreigners and the Foreign Expert Work Permit, were combined into a single unified framework, namely the Permit System for Foreigners in China, administered by the State Administration of Foreign Experts Affairs (ILO and IOM, 2017). Under the new, points-based framework, three types of visa are issued: A (issued to individuals with high-end skills who score 85 or more points), B (issued to professionals who score between 60 and 84 points) and C (issued to other foreign workers who score fewer than 60 points). Type A visas are issued to approximately 16 per cent of experts, and type B and type C visas to some 61 per cent and 22 per cent of experts, respectively(-Dezan Shira & Associates, 2017).

Type A visa applicants can expect shorter processing times and paperless verification during the application process and lower requirements as to age, education level and work experience. On the other hand, they have to meet other specific conditions (Dezan Shira & Associates, 2017). For example, applicants can obtain a type A visa if they are considered entrepreneurial or new industry talent,[9] have worked in a senior management position or high-ranking technical role at a Fortune 500 company, or earn six times more than the local average.

Type B visas are primarily issued to skilled workers in specific, in-demand fields, with a bachelor's degree or above and two years' work experience in a relevant field. Workers with experience and qualifications in STEM subjects are more likely to apply successfully for type B visas. Validity periods for type B visas are longer than for type A visas. Applicants must provide all relevant documentation in original paper form.

A recent reform that came into effect in August 2019 has prolonged the validity period of work permits from two to five years for workers with high-level and in-demand skills, including, for example, individuals working in industries identified as key development areas (KPMG, 2019).

9 "Applicants are considered entrepreneurial and new industry talent by [...]: Offering a new product or service requiring a patent, three years of stable investment, real investment not below $500,000, as well as a 30 per cent stake or above in the enterprise; Earning three years of annual revenue not below RMB 10 million, or; Planning to work in a senior management position or as a technical expert in innovative industries that align with the requirements of regional administrative departments..." (Dezan Shira & Associates, 2017).

In 2019, China also introduced the National High-end Foreign Expert Recruitment Plan in order to attract high-level foreign experts in key priority fields with a view to fostering innovation in science and technology. The Plan not only focuses on senior managers and entrepreneurs, but also on young highly-skilled individuals in areas of the economy affected by skills shortages. Those recruited under the Plan are encouraged to remain in China long-term.[10]

Germany

Individuals who are nationals of an EU or European Economic Area member country, in addition to Swiss nationals, do not have to apply for a visa in order to work in Germany (Auswärtiges Amt, n.d.; BA, n.d.-c).

If no bilateral agreement or other legislative decree applies, approval from the BA is needed before a German diplomatic mission can issue a work visa. An example of such a legislative degree is the whitelist, regularly prepared by BA (BA, n.d.): BA approval is not required for the immigration of a non-German national who has recognized vocational qualifications corresponding to one of the bottleneck occupations listed in the whitelist. Currently, the only IT occupations included on the whitelist are in software development (*Klassifikation der Berufe 2010*, group 43413; see BA, 2019). Generally, BA approval is based on considerations such as ensuring that working conditions, including wage levels, for the proposed employment of a foreign national are comparable to those of workers already in Germany. The work visa is also conditional upon receiving confirmation that no equally qualified German national or foreigner holding the same rights as a German citizen is available for the employment position.

The European Union Blue Card[11] is a time-limited residence title introduced in August 2012 pursuant to a directive on highly-qualified employment. The Blue Card is offered to highly-qualified immigrants from non-EU countries and offers them the prospect of obtaining a permanent right of residence. Current Blue Card regulations in Germany stipulate that ICT specialists applying for a Blue Card must have a binding job offer or employment contract in Germany with an annual income of at least €41,808 (US$49,243)[12] and a recognized foreign or comparable foreign higher educational qualification (BAMF, 2020).[13] The Blue Card is valid for a maximum of four years, but after 33 months, holders of the card can be issued with an unlimited residence permit,[14] provided they have maintained their employment as a highly-qualified person, made obligatory social contributions or comparable statutory pension and insurance payments, and met all other prerequisites for an unlimited residence permit. In 2017, 84.5 per cent of all Blue Cards were issued in Germany (BAMF data). In 2018, a total of 27,241 Blue Cards were issued in Germany: an increase of 25.4 per cent compared to the figures for 2017. Most Blue Card holders come from India (27.7 per cent), China (8.0 per cent), the Russian Federation (5.9 per cent), Turkey (4.8 per cent) and Brazil (3.7 per cent).

The Bundestag (the German Parliament), recently adopted the Skilled Labour Immigration Act (BMI, n.d.), which entered into force on 1 March 2020. The new Act stipulates that skilled workers with a recognized tertiary or vocational education qualification can take up employment in Germany. An exception is made for ICT specialists, however, who can take up employment even without a formal qualification if they have at least three years' work experience, a monthly income of at least €4,020 (US$4,735)[15] and a conciliation agreement with BA.[16] Employers, and employers' and workers' organizations, have warmly welcomed the adoption of the new Act (Research mission interviews, Germany).

Singapore

Several different visa categories, known as "passes" are offered to foreigners seeking employment in Singapore, and the type of pass that may be offered usually depends on skills level of the applicant.[17] These include passes for professionals, skilled and semi-skilled workers, other types of work permits, and passes for students and family members. Migrant ICT specialists will most commonly hold either a visa for professional workers or for skilled workers (an Employment Pass, Personalized Employment Pass or S-Pass). Employment Passes are issued to foreign professionals, managers and executives. Applicants need to earn at least SGD3,600 (US$2,623) a month and hold certain qualifications. Personalized Employment Passes are issued to high-earning existing Employment Pass holders or overseas foreign professionals. A

10 For further information, see: chinainnovationfunding.eu/project/2019-high-end-foreign-experts-recruitment-plan/
11 European Union Blue Card Directive, 2009
12 Exchange rate calculated on 7 August 2020.
13 For certain workers whose skills are in particular demand (*Mangelberufe*), including certain ICT specialists, the minimum annual income required for application is lower than the standard annual minimum income of €53,600.
14 Shortened to 21 months if adequate knowledge of German (level B1) can be proved.
15 Exchange rate calculated on 7 August 2020.
16 *Vermittlungsabsprache*: in some cases, the qualification recognition process requires the applicant to complete additional theoretical or practical training in Germany before the qualification is considered as equivalent.
17 Information provided by the Ministry of Manpower.

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Personal Employment Pass offers greater flexibility than an Employment Pass. S-Passes are issued to mid-level skilled or semi-skilled individuals. Applicants need to earn at least SGD 2,300 (US$1,675) a month and meet certain assessment criteria.[18]

In 2018, about 11 per cent of foreign nationals were working under an Employment Pass, and 12 per cent under an S-Pass (MOM, Research and Statistics Department, n.d.).

The number of S-Pass holders a company can hire is capped at 15 per cent (service sector) to 20 per cent (all other sectors) of the company's total workforce. The S-Pass quota is to be reduced to 10 per cent in 2021.

In 2018, in a move to give Singaporeans access to better jobs, the Government of Singapore broadened Fair Consideration Framework, job advertising requirements, and tightened requirements for the employment of foreign talent. Under the amended Fair Consideration Framework, employers must advertise a job for at least 14 days prior to the submission of an Employment Pass application. That new requirement is not, however, perceived as a significant barrier impeding labour migration (Research mission interview with the recruitment agency EMA partners, Singapore).

However, specific programmes have been established to avoid negative repercussions in potential economic growth areas, particularly those experiencing highly-skilled labour shortages. On 30 July 2019, for example, the EDB and Enterprise Singapore launched Tech@SG, a targeted programme to assist technology companies to grow in Singapore and expand in the region, on a two-year trial basis (EDB and Enterprise Singapore, 2019). Under the new programme, Employment Pass applications submitted on behalf of core team members by qualifying companies in the digital, medtech, biotech, cleantech, agritech and fintech sectors will be expedited with a view to enhancing the capacity of tech companies to fill key tech specialist positions.

Digital Industry Singapore is a joint office of the EDB and IMDA. It provides a one-stop-shop interface through which the Government engages with business enterprises in the technology sector.[19] That streamlined approach facilitates efforts by the Government to understand companies' needs with a view to establishing global technology leaders, strengthening local champions and nurturing future-ready talent in Singapore. The overall goal of Digital Industry Singapore is to help the Government to establish Singapore as an Asian and global technology hub.

3.3.2 Pre- and post-arrival support

Canada

A key element of successful integration programmes in Canada is the provision of a wide range of support services and programmes for immigrants and refugees that promote their full participation in economic, social and cultural life. Immigrants can access services free of charge until they are granted citizenship. Canadian citizens, temporary residents and refugee claimants are not eligible for federal services, but they enjoy access to the settlement services funded by certain provinces and territories. Services are delivered by third-party providers, both in-person and online. Service provider organizations include non-profit organizations, charities, ethnically-based community organizations, educational institutions, including schools, colleges, and universities, and private sector entities.

Federal settlement services under the Settlement Program include:

- Information and orientation services, to help newcomers make informed decisions about their settlement and better understand the country's laws and institutions;
- Language training to help newcomers access information, find employment and establish social connections;
- Community support services that connect newcomers to public institutions and local community groups; and
- Services to put immigrants in contact with employers and provide information about foreign credential recognition pathways with a view to helping newcomers look for, obtain and retain employment in line with their skill sets and education levels.

Provincial and territorial governments also provide immigrants and refugees with key health, education, social and other services that facilitate their integration into Canadian society.

Pre-arrival services are designed to prepare immigrants for their life in Canada. IRCC has established in-person offices in the country's top three countries of origin, namely China, India and the Philippines. One of the many organizations providing pre-arrival support is ICTC, a non-profit entity that, inter alia, provides labour market-oriented support for ICT specialists,

18 Exchange rate calculated on 7 August 2020.
19 For further information, see: www.imda.gov.sg/for-industry/Digital-Industry-Singapore-DISG

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Box 3.2 Zentrale Auslands- und Fachvermittlung (ZAV) (International Placement Service)

The *Zentrale Auslands- und Fachvermittlung* (ZAV) (International Placement Service), a department of BA, liaises between employees and employers with a view to placing workers from abroad in job positions in Germany. It also promotes the integration of foreign workers into the German labour market. ZAV provides only pre-arrival employment services. Recruitment activities are focused on engineers, IT professionals, physicians and nurses, professional drivers, and construction, hotel and catering professionals. ZAV has recently organized recruitment activities for ICT specialists in Brazil, the Republic of Korea and Mexico.

For its placement activities, ZAV reviews the job résumés of jobseekers living abroad and registers those jobseekers who have a good chance of finding employment. ZAV counsellors also provide résumé writing guidance. In some cases, companies approach ZAV to request its support in recruiting workers from abroad. ZAV also sends the profiles of suitable jobseekers to potential employers. Every year, ZAV provides counselling to between 4,000 and 5,000 jobseekers. Of those, approximately 800 are IT experts or engineers. ZAV aims to place 300 IT experts and engineers in jobs in Germany every year.

Source: Research mission interview with ZAV.

including job-readiness assessments and job-search counselling. On the basis of its job readiness assessments, ICTC may offer upskilling recommendations (Research mission interview with ICTC, Canada). In addition, ICTC offers several three-week bridging programmes that focus on skills updating.

Post-arrival services include job-search assistance for up to six months after arrival. Activities encompass job résumé writing coaching, and coaching sessions on workplace culture and effective communication skills. ICTC partners with other community organizations that provide a range of settlement services. Some 60 per cent of new immigrants take language courses (Research mission interview with ICTC, Canada).

The Federal Internship for Newcomers Program addresses key barriers to newcomer participation in the Canadian labour market by helping skilled and experienced newcomers gain relevant work experience in the public sector in fields such as administration, IT and programme/policy support. Since its inception in 2010, 44 federal organizations, in addition to several provincial and municipal organizations, have provided short-term work experience, training, and mentorship to almost 800 newcomers to support their integration into the Canadian workplace.

In the view of employers, the sheer number of programmes in Canada is overwhelming, making them difficult to navigate (OECD, 2019). Employers have also noted, however, that, while they have used all the programmes provided by the Government to recruit foreign talent, they were still unable to recruit sufficient numbers of skilled immigrants. Indeed, a number of stakeholders have noted that the tech sector is growing more rapidly than the capacity of government programmes to support the sector (Association for Canadian Studies and the Immigrant Employment Council of British Colombia, 2018).

Germany

In recent years, Germany has adopted a number of measures to attract skilled workers, such as improved information and placement services. Furthermore, the "Make it in Germany" web portal, established by BMWi in 2012,[20] aims to provide information about living and working in Germany to academics in STEM fields in non-EU countries (IW, 2019). The portal also guides migrants to a bilingual German/English hotline that they can call to ask more detailed questions related to their personal situation. The hotline provides information on a range of topics, including job searches, recognition of foreign vocational qualifications, entry and residence regulations, and ways to learn German. BA operates a web portal with a range of information for migrants in German, English and Arabic (BA, n.d.-d).

BA has also established the *Zentrale Auslands- und Fachvermittlung* (ZAV) (International Placement Service), which provides counselling and job placement services to skilled migrants (see Box 3.2).

Post-arrival, BA offers support, including German language courses, to EU citizens within the context of the "Your first EURES job" programme (for persons under 35) and the EURES Reactivate programme (for persons aged 35 and over). Under those programmes, workers moving from one EU country to another can obtain financial assistance to offset relocation costs. Non-EU citizens in Germany can apply for German language courses through Federal Office for Migration and Refugees (BAMF), which also provides language and

20 For further information, see: www.make-it-in-germany.com/en/

integration courses for refugees (Research mission interview with BA, Germany).

Immigrants may also need to update their technical skills and individuals who register as jobseekers with BA may be eligible to enrol in upskilling courses.

In Munich, a major ICT hub in Germany, the Chamber of Commerce and Industry (IHK) has established an integration team to provide assistance to recent immigrants who wish to enrol in apprenticeship programmes.

An upper-intermediate level of German is often required, corresponding to "independent user" level (B2) under the Common European Framework of Reference for Languages.[21] German language requirements are one of the most significant barriers preventing immigrants from enrolling in VET courses (Research mission interview with IHK, Germany).

China and Singapore

Compared to Canada and Germany, there are few pre- and post-arrival services provided for migrants in China and Singapore. In general, China focuses on promoting the return migration of highly-skilled Chinese nationals living abroad (see section 3.2.3 for details) rather than seeking to attract workers who are not Chinese nationals (ILO and IOM, 2017).

Immigrants acquiring Singaporean citizenship must enrol in the "Singapore Citizenship Journey" programme, which aims to enhance their understanding of Singaporean values and the country's history.

3.3.3 Recognition of foreign qualifications

Challenges related to the recognition of foreign qualifications often constitute a significant impediment to migration and can significantly restrict migrants' access to the labour market. Procedures that migrants must follow to obtain recognition of qualifications they obtained prior to their arrival in their destination countries are often extremely onerous and time consuming. Migrants with engineering qualifications often have great difficulty in getting their qualifications recognized in Canada, for example. For unregulated occupations, proof that a formal qualification level has been obtained may still be required in the visa application process. While procedures for this can still be lengthy, they are, in general, less burdensome. Recognition of qualifications, even if not legally required, can sometimes be useful if it increases the trust of potential employers in credentials obtained abroad.

Countries often enter bilateral labour migration agreements, not only to enhance migration governance, but also to address skills gaps and shortages. To facilitate that process, the Guidelines for skills modules in bilateral labour migration agreements were published by ILO in 2020.

The portability of credentials is critically important in international labour migration. An important mutual recognition framework relevant to the ICT sector is the International Engineering Alliance Washington Accord, which has been signed by 20 countries, including Canada, China, India, Japan, Singapore, the United Kingdom and the United States (International Engineering Alliance, n.d.). The Accord is a multilateral agreement among bodies responsible for the accreditation or recognition of tertiary-level engineering qualifications that facilitates the mobility of professional engineers, including in the area of ICT.[22]

Canada

As mentioned above, engineering occupations are one of several occupations that are tightly regulated in Canada. Immigrants require recognition of their qualifications if they wish to work as a licensed engineer and recognition procedures in engineering occupations take between 6 months and 2 years to complete (Research mission interview with ICTC, Canada). Some ICTC specialists will be affected by those rules.

In the private sector, many studies have highlighted the reluctance of employers to recognize foreign credentials. Over the last 20 years, however, numerous governmental programmes have been launched to facilitate recognition. A way for employers to assess skills by looking beyond credentials is to include skills-based testing in the recruitment process. It should be highlighted that Canada has concluded agreements with Australia that allow accountants and engineers to work in either country without re-licensing.

China

In order to obtain a work visa for China, applicants must have their diplomas verified by the Chinese Service Center for Scholarly Exchange. According to a recruitment company, that process can take over a month to complete.

21 The Common European Framework of Reference for Languages classifies language skills into six levels, with letters denoting three broad categories: A indicates a "basic user", B denotes an "independent user" and C denotes a "proficient user". Proficient user (C1) is the language level generally required by an individual wishing to pursue university-level studies.

22 For further information, see: www.ieagreements.org/accords/washington/

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Under the Permit System for Foreigners in China, experts are required to have at least a bachelors' degree. However, that requirement is waived for experts in the field of technology. Employers in the field of culture and education that intend to employ foreign experts are required to obtain a special permit, namely a "Qualification Certificate for Employing Foreign Experts" prior to employing foreign experts (State Administration of Foreign Experts Affairs, 2018).

Germany

Difficulties related to the recognition of formal qualifications is one of the most significant barriers to immigration in Germany. In general, however, ICT specialists do not need to undergo a formal recognition process, as ICT occupations are unregulated. As a result, very few ICT specialists have been subject to a qualification recognition process (Bundestag, 2019a). Within the EU, the Bologna Process seeks to bring more coherence to higher education systems.[23] Likewise, the European Qualification Framework is designed to enhance the comparability of qualifications within EU member States.

Nevertheless, in the context of visa applications, highly skilled individuals may need to prove that they have obtained a tertiary education qualification. In that connection, the *Anabin Infoportal zu ausländischen Bildungsabschlüssen* (Information portal on foreign educational qualifications), maintained by the German Standing Conference of the Ministers of Education and Cultural Affairs provides information on equivalence between foreign diplomas or tertiary training courses and German qualifications (Anabin Infoportal zu ausländischen Bildungsabschlüssen, n.d.). That information can help migrants assess whether qualifications they obtained in their home countries are likely to be recognized in Germany. One shortcoming is that the information is only provided in German. If Anabin does not list a degree, the potential migrant can request the degree to be assessed. That process takes between two and five weeks and costs approximately €200 (US$235)[24] (Research mission interview with ZAV, Germany).

To foster transparency and reduce mistrust among German employers, BMWi has established the online BQ-Portal,[25] which provides German companies with information about foreign vocational training systems and the subjects covered by popular professional courses, including IT training courses in various countries (BMWi, n.d).

Singapore

The Association of South East Asian Nations (ASEAN) Mutual Recognition Arrangements were adopted to promote the mobility of professionals within the ASEAN economic community by facilitating community-wide recognition of qualifications, work experience, requirements met, and licenses or certifications granted by relevant authorities in ASEAN member States. The Arrangements incorporate the ASEAN Qualifications Reference Framework, which enables stakeholders to compare qualifications issued in all ASEAN member States and facilitates the development of policies on lifelong learning and the recognition of learning that occurs outside formal educational institutions. The Framework also promotes learner and worker mobility. To date, however, no ASEAN mutual recognition arrangements that apply specifically to ICT specialists have been adopted (ASEAN, n.d.).

3.3.4 Promoting international student mobility

International cooperation among educational institutions and student exchanges can equip young people with a global mind set and broaden their outlook. Establishing relationships among master's and doctorate students may also pave the way for future exchanges, including in academic research. Offering study opportunities to international students may help widen a country's talent pool, particularly if it is difficult to attract sufficient numbers of students locally. Research cooperation is an international endeavour because specific expertise is often found across numerous countries. All four countries examined in this study have established international student exchange programmes and encourage partnerships with universities abroad. Financial assistance may also be available to enable students to study overseas. Section 3.1.3 of this report provides an overview of international student migration numbers in the four countries.

Tuition is free in German public universities, and no differentiation is made between German and foreign nationals in most regions. In contrast, in Ontario, Canada, international student tuition is higher than for domestic students, because it is not subsidized by the province (Research mission interview with Ontario Ministry of Colleges and Universities, Canada). One long-term talent attraction strategy that Singapore has pursued is the offer of scholarships to foreign talent in ICT-related subjects. More general programmes, such as the ASEAN scholarship scheme or

23 https://ec.europa.eu/education/policies/higher-education/bologna-process-and-european-higher-education-area_en
24 Exchange rate calculated on 7 August 2020.
25 The Portal is available at: www.bq-portal.de/Anerkennung-f%C3%BCr-Betriebe

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general undergraduate scholarships, are also available for promising foreign students.

The NUS Overseas College Programme, which initially provided assistance that allowed students to study for a year in Silicon Valley in the United States, now provides scholarships for students wishing to study in 12 locations. To date, more than 3,000 students have received assistance through the Programme, which has indirectly led to the establishment of some 650 innovative start-up companies (Research mission interview with NUS, Singapore). In Germany, TUM has established TUM Asia, a campus in Singapore, which offers dual study programmes. International students at TUM Asia are offered internships in Germany with Infineon, a semiconductor company (Research mission interview with Infineon, Germany). Singaporean students can also enrol in entrepreneurship programmes at partner universities overseas. Although Silicon Valley is the top destination choice, placements in China are also very popular (Research mission interview with NUS, Singapore).

3.3.5 Impact of labour migration

In light of ongoing skills shortages and global competition for talent, the immigration of ICT specialists was viewed positively by many interviewees in all four countries. The Canadian, Chinese and German Governments have recently simplified visa application procedures in order to attract highly-skilled individuals, as it is assumed that the migration of skilled labour will benefit the economy. In Canada, the introduction of a streamlined entry visa management system has been welcomed by employers. According to a study published by the German Economic Institute (IW), some 1.8 million immigrants working in a STEM field contributed approximately €186.1 billion (US$219 billion)[26] to added value in Germany (IW, 2018). Furthermore, the German Government has recently reformed migration policies to facilitate the immigration of certain categories of workers, including ICT specialists.

In Singapore, policies have been adopted to ensure that the proportion of foreigners in the labour market remains below a certain level, in accordance with the wishes of the country's population. In fact, according to a survey conducted by the Institute of Policy Studies in 2016, the proportion of respondents who believed that the presence of large numbers of foreign nationals undermined societal cohesion in Singapore increased from 38.9 per cent in 2010 to 48 per cent in 2016 (Koh, 2018). Nonetheless, exemptions have been made, particularly for ICT specialists, to address persistent skills shortages, which, if left unaddressed, could negatively affect the country's economic development.

To summarize, the immigration of ICT specialists is generally viewed positively in destination countries, as it leads to a "brain gain" and helps address skills shortages.

From the viewpoint of countries of origin, a corresponding "brain drain" may be an issue of some concern. For many years, research in the area of migration focused, primarily, on how the so-called "brain drain" has affected countries. In recent times, however, the debate has shifted towards looking at what has been dubbed "brain circulation", a phenomenon that has affected India, for example (ILO, 2019). Furthermore, many countries wish to encourage their highly-skilled ICT specialists to return home not only to offset any potential "brain drain", but also to benefit from the knowledge that those specialists have gained while working abroad.

26 Exchange rate calculated on 7 August 2020.

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4

Key findings and possible policy responses

4.1 Key findings

4.1.1 Digitalization of the economy – challenges for the labour market

Digital technologies, which can bring about product and process innovations and facilitate new ways of doing business, are now having a significant impact on production processes and work organization across all sectors. However, rapid technological change also poses several challenges. There are concerns about future job losses as a result of automation and the adoption of AI, widening gender disparities in digital technologies and an increase in discrimination and inequalities due to inherent algorithm biases[1]. Furthermore, access to more advanced production technologies remains highly unequal.

Value-added in the ICT sector and the employment of ICT specialists across sectors has been on the rise in recent years in all four countries. Although digital technologies are developing fast, the extent to which they are being adopted across different sectors of the economy has varied and the potential they offer is far from being fully exploited, in part because of ongoing labour and skills shortages.

Private and public companies across all sectors are struggling to attract and retain ICT specialists. Staff fluctuation remains high, as workers continue to seek better opportunities elsewhere. ICT specialists in all four countries earn wages that are much higher than average. High wages make the recruitment of ICT specialists particularly difficult for SMEs. In addition to offering competitive wages, companies seek to attract workers by offering other amenities, such as continuous training and a "modern" work environment.

Flexible work schedules are more widespread among ICT specialists than among many other occupational groups. Flexible schedules provide advantages for employers, as ICT work is often project based, with more work-intensive cycles. They can also provide advantages for employees, as flexible work schedules can help workers achieve a good work-life balance. On the other hand, long working hours, work-related stress and related physical and mental health problems may, to some extent, limit the attractiveness of ICT occupations. Indeed, long working hours are often reported in the ICT sector, particularly in China.

One potential risk related to online platform work is that it might affect workers' skills development, as the responsibility for investing in skills development lies, in essence, with individual workers. On the positive side, online platform work can provide employment opportunities to workers who find it difficult to access the labour market, and trade unions in China and Singapore, in particular, perceive online platform work as a way for mid-career and older workers to gain employment. The German trade union IG Metall has, moreover, established a counselling service for crowd workers, which workers can access even if they are not a trade union member, through which it provides advice and assistance in a number of areas, including on legal issues.

Except in large companies in Germany, working conditions in the ICT sector are seldom regulated by collective agreements. In Germany, BMAS has initiated a dialogue process involving employers' and workers'

1 An algorithm helps make decisions by harnessing large volumes of data. However, the decisions from an algorithm can be biased if the algorithm relies on unrepresentative data that reflects biases in society.

organizations on Work 4.0, through which civil society, research organizations, and political stakeholders are seeking to address key issues related to the future of work and discussing possible policy measures to enhance working conditions and promote the establishment of an integrative labour market.

4.1.2 Gender issues

In all four countries, and particularly in Germany, the proportion of women among ICT specialists is well below economy-wide averages. There are, however, large variations in female employment by occupational subgroup, with the lowest proportion of women evident in software development and programming, and higher proportions of women working in occupations in which ICT is used in the media, health and business administration, or when there is a significant graphic and arts component in their job roles and tasks. Some reasons why ICT occupations are less attractive for women are the long hours that ICT workers are expected to work and the lack of childcare facilities. Entrenched stereotypes regarding appropriate jobs for women may also explain the low proportion of women working as ICT specialists, as they can discourage women from enrolling in ICT-related study fields. Such negative stereotypes can start as early as pre-school, while the dominance of men in the ICT field and in ICT teaching programmes, including at higher education establishments, can further reinforce those stereotypes.

Policy measures adopted by countries include the provision of vocational orientation and guidance, coding competitions, women's awards, the identification of female role models, and the establishment and strengthening of women's professional networks. However, current low female participation rates in the ICT field suggest that further coordinated and targeted efforts are required to encourage women to consider ICT professions and to enhance the attractiveness of ICT occupations for women.

4.1.3 Ageing workforce

Overall, ICT specialists tend to be younger than the average worker, in particular in new digital technology job roles. However, the proportion of ICT workers who are middle-aged or older is increasing. Companies ideally prefer to employ younger workers with work experience. As those workers are scarce, university graduates often have a good chance of finding employment. Job searches for older workers, however, are more challenging, despite the significant skills shortages faced by many ICT companies.

For companies to find and retain workers with the right skills, upskilling and reskilling of middle-aged and older ICT specialists is essential. Good practice examples suggest that ICT companies can often leverage the untapped potential of older workers. To explore the potential of older workers, their skills level and skills needs must be assessed, and skills development plans need to be implemented.

4.1.4 Skills shortages and skills gaps

All four countries have faced significant challenges in recent years in connection with skills shortages and skills gaps. This is likely to remain a pressing issue for the foreseeable future. In general, the level of skills required by employers is rising in all four countries, as ICT specialists are required to develop, apply and implement increasingly complex technologies.

In Singapore, two thirds of ICT specialists hold a university degree; this compares to 55 per cent in Canada and 37 per cent in Germany. A comparison with China is not possible due to a lack of relevant publicly available data.

In all four countries, there is increasing demand for skills in digital technologies, including AI, cloud computing, big data and cybersecurity, and in business intelligence and analytics. Knowledge of specific programming languages is also highly desirable. The ability to work in interdisciplinary fields and some knowledge of other study fields is becoming increasingly important in all four countries as IT technologies become increasingly complex and more and more integrated into all sectors of the economy.

In all four countries, soft skills are becoming increasingly important for ICT specialists. This stems from the development and use of technologies (critical thinking, analytical thinking, creative thinking), coping with technological change (an ability to learn, flexibility), and the organization of work and customer relations (understanding processes in different sectors, teamwork, leadership, communication, service orientation, business and management skills). The labour market is increasingly rewarding IT specialists with key non-technical skills with higher salaries.

4.1.5 Skills development

In terms of skills development policies, all four countries must address three main challenges:

a. The need to address skills shortages by increasing the number of students admitted to ICT courses at all educational levels;

b. The need to amend VET and higher education course curricula to reflect the short- and long-term needs of the economy and society; and

c. The need to ensure that workers can update their skills or retrain.

Although increasing numbers of students are studying subjects related to ICT, their growing numbers have failed to keep pace with the expanding needs of the ICT sector. One common challenge impeding efforts in all four countries to scale up ICT education at higher education institutions is a shortage of suitably-qualified academic teaching staff. Competing for students' interest is another challenge, particularly at VET institutions.

In all four countries, input is sought from companies and from industry associations or sector councils to facilitate curriculum development. However, consultation processes are not always formalized, and effective cooperation depends on the existence of a culture of dialogue and perceived mutual interests. Indeed, conflicting views have sometimes emerged as to the long-term and short-term objectives of higher education.

Higher education institutions have started to integrate cross-domain and generic skills into their curricula, but there is scope for further curriculum development. Top ranking universities in China are increasingly focusing on innovation and, in all four countries, entrepreneurship training is being offered to students.

The complexity of technologies and their application across numerous sectors mean that interdisciplinary learning is crucial. Three key strategies can promote an interdisciplinary approach, namely enhancing the amount of multidisciplinary learning content in ICT study fields, enhancing the amount of ICT-related content in other study fields, and creating relevant inter- and multidisciplinary study courses. New combined ICT study programmes have been set up, mainly in combination with media, health, and engineering studies. One of the current challenges in all four countries is introducing AI into other disciplines and promoting multidisciplinary research.

Flexibility in education and upskilling pathways within the formal VET and education system is essential for meeting the skills needs of companies and countries. Singapore has established a flexible system of pathways between the upper secondary and tertiary levels. In the field of ICT, combining formal and non-formal education has become increasingly important. How much weight is given to work experience, to certified continuous training and to students' formal qualifications varies among the different countries.

In all four countries, internships have been integrated into university curricula in tertiary education, and may also be entered into voluntarily, in order to improve graduates' employability. In all four countries, internships are often used by companies as a recruitment channel.

Given the high speed of technological development, ICT specialists participate more frequently in continuous training than specialists in other fields. Continuous training, which can take various formats and can vary in duration, encompasses, inter alia, informal workplace learning, self-directed online training, structured company-based training, training to obtain certificates, and ICT boot camps for career changers. Continuous education is also offered at universities in all four countries and various VET institutions have established continuous education programmes, particularly in Germany and Singapore.

The responsibilities of workers, employers and governments in terms of lifelong learning strategies vary among the four countries. Training costs tend to be borne by both the individuals receiving training and companies. Although governments have enacted policies to promote the upskilling and reskilling of workers, those policies tend to focus on specific groups of individuals or companies.

In Canada, for example, although companies provide continuous training for their workers, the main responsibility for upskilling remains with the individual worker or jobseeker. Several targeted government programmes have been developed for specific groups of individuals, sectors and regions. In Germany, companies provide more continuous training for ICT specialists than for other occupations, and ICT workers invest considerable time in pursuing free online courses. The German Government has recently decided on a new strategy for continuous training, which will provide additional support for the necessary skills adaptation for employed workers and strengthen the quality of vocational guidance provided to adults. The Government of Singapore has adopted a robust workforce skills development policy and is making substantial investments in continuous education and training, and in retraining and professional conversion. In Singapore and in China, trade unions also organize continuous training for workers.

4.1.6 International labour migration

Both Canada and Singapore have a long history of immigration, and foreign-born immigrants account for some 30 per cent of the workforce in both countries. Germany become a net-immigration country in the 1960s and approximately 10 per cent of that country's workforce is now foreign-born. The proportion of foreign-born ICT specialists is higher than in other fields in both Canada and Germany, and around average in Singapore. In China, the percentage of skilled and highly-skilled foreign workers, including ICT specialists, remains low.

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Incentives to encourage the relocation of ICT specialists from less developed countries to Canada, Germany, Singapore and China include higher wage levels and standard of living, and higher quality of the education system and ICT infrastructure. International exposure is also a decisive factor for migrants, as it can provide them with career development opportunities throughout their working lives.

Whereas geographical and cultural proximity, as well as good command of English and national languages, can facilitate labour migration, insufficient language skills are a major barrier to relocation. Poor language skills limit workers' prospects for employment and impede their integration into their host societies. Investments in language training may therefore be needed. It should be noted, however, that the extent to which workers must be able to communicate in the national language of the destination country often depends on the proportion of international staff at the workplace of the destination country.

Migration policies and visa regulations are one of the main factors shaping the volume and structure of labour migration. In Canada, a human capital approach has been pursued and a points-based system established. That system gives considerable weight to an individual's formal qualifications, language skills and work experience. The system has been criticized for its long waiting periods and its lack of orientation towards labour market needs. Employers are often reluctant to recruit workers from outside Canada because of the costs associated with that process and the uncertainty regarding whether visas will, in fact, be granted for the workers they wish to recruit. Employers therefore tend to give preference to hiring migrant workers who are already in the country and have experience of working in Canada. Canada has also benefited from the recent tightening of migration policies in the United States, which has made it easier to attract ICT specialists, even though Canada is not as competitive as the United States in terms of wages. Canada has, predominantly, attracted migrants from China, India and Europe.

Germany benefits from the free movement of labour for citizens of EU member States. Indeed, the unrestricted movement of labour within the EU is one of the reasons why Germany continues to attract large numbers of ICT specialists mainly from other European countries, many of which suffer from high levels of unemployment. Furthermore, jobs in other EU States often pay significantly less than equivalent jobs in Germany. The Skilled Immigration Act, which came into force in March 2020, facilitates the immigration of ICT specialists by allowing them to apply to come to Germany on the basis of their years of relevant work experience instead of their formal qualifications. In general, procedures for recognizing qualifications and other immigration processes have been streamlined. Efforts have also been made to improve immigrants' access to language training and to bridging and upskilling courses. It remains to be seen whether the new Act will successfully address the challenges impeding the recruitment of workers from outside the EU.

In Singapore, different visas are offered for different types of worker. The type of visa issued depends, primarily, on the worker's skills level. Because Singaporean companies are finding it difficult to recruit adequate numbers of ICT specialists, visa exemptions have been made to facilitate the recruitment of foreign nationals by companies operating in growth areas such as medtech, biotech, cleantech, agri-tech and fintech.

Until recently, China imposed relatively restrictive visa regulations. In 2017, however, a new national points-based framework was introduced. Under that framework, three types of visa are issued: A (issued to individuals with high-end skills), B (issued to professionals), and C (issued to other foreign workers). The new framework has also helped to streamline the work permit application process by standardizing and simplifying the documentation and procedural requirements.

Increasing attention is being given in China to return migration, and policies have been put in place to attract very high-skilled Chinese workers to take up positions at Chinese academic institutions. Government agencies in Singapore also have increased their outreach efforts to attract overseas Singaporeans back to Singapore to work.

In Canada, the labour market absorbs the vast majority of foreign ICT specialists, as clearly shown by their low unemployment rates. Statistics show, however, that it can take several months for an ICT specialist to find his or her first job. If immigrants were offered additional pre-arrival and settlement services, that period could be reduced. Pre-arrival services include job-readiness assessments, upskilling courses and job-search counselling. Those services enable potential migrants to strengthen their employability while still in their country of origin. Settlement services provide migrants with free language and job-search skills training. Settlement services may also include skills assessments for ICT specialists. In Germany, pre-arrival services include placement and counselling services, in accordance with visa regulations. In contrast to Canada, one of the key stakeholders in Germany providing placement and labour market-related counselling is the public employment service agency. However, further efforts are needed to be done in the area of providing language courses to skilled and highly-skilled immigrants.

Many students migrate to Canada, Germany and Singapore to enrol in high-quality tertiary education courses that are unavailable in their countries of origin.

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This is particularly the case at the master's and doctorate levels. For Canada and Germany, students' main countries of origin are China and India. Other factors that encourage young people to study abroad include the fact that a study course outside their country of origin will provide them with international exposure, which is personally enriching and can increase their employability and access to labour market with a degree obtained in the country of destination. While Germany is an attractive destination for students because of its high-quality education and free tuition, the high quality of education and facilitated labour market access may be the main reasons students choose to study in Canada. In Singapore a number of scholarship programmes are offered, particularly for students from ASEAN countries. In general, it is in the interests of destination countries to retain international students following their graduation in order to address skills shortages.

▶ 4.2 Possible policy responses

This section outlines a number of potential responses that governments, employers' and workers' organizations and education and training institutions can take to address skills shortages and ensure better governed migration for ICT specialists. To achieve those objectives, governments and employers' and workers' organizations should engage, as appropriate, in social dialogue at all levels. Where possible, governments should work together with employers' and workers' organizations to develop policies and strategies to address the challenges faced by the ICT sector and ICT specialists in particular. It is also crucial for education and training institutions to work with social partners with a view to developing and implementing effective skills development policies and strategies.

4.2.1 For governments

a. Promote coordination between the ministries and authorities responsible for skilled ICT workers and other relevant national and local governments and institutions.

b. Develop, implement and enforce labour laws and regulations to ensure that the fundamental principles and rights at work and ratified international labour conventions protect and apply to all ICT workers.

c. Promote practices that advance a good work-life balance and ensure that workers are not required to work unduly long hours over an extended period of time.

d. Conduct an assessment of the working conditions of platform workers and ensure that social protection is extended to platform workers in the ICT sector.

e. Invest in skills forecasting systems to enhance understanding of current and future skills needs.

f. Develop policies and strategies on lifelong learning at the national and local levels in consultation with workers' and employers' organizations.

g. Promote access to continuous training for SMEs to strengthen their capacity to upskill and reskill their workers.

h. Promote continuous training in the digital economy, including upskilling and reskilling, by using methods such as the provision of subsidies and fostering partnerships with industry.

i. Promote measures that encourage more women to study STEM subjects and pursue careers in ICT, inter alia, by raising their awareness of potential ICT careers, improving the ICT working environment for women, addressing negative stereotypes in early childhood education, and promoting professional and role model networks.

j. Ensure that skills assessments are undertaken as part of the pre- and post-arrival services offered to migrant workers, offer bridging training courses, including language training, to upskill potential migrant ICT specialists and provide guidance to employers wishing to recruit ICT workers from abroad.

k. Streamline procedures for the recognition of formal qualifications from foreign institutions, work experience and other prior learning.

l. Adopt measures that facilitate the integration of immigrant ICT workers and their families into society.

m. Simplify and expedite visa application processes and administrative procedures in destination countries to help tackle acute talent shortages.

4.2.2 For education and training institutions

a. Review curricula on a regular basis to ensure that students on ICT courses learn an appropriate mix of foundational, theoretical and practical skills.

b. Consult with employers' and workers' organizations on areas where curricula should be regularly updated to reflect evolving skills requirements.

c. Promote interdisciplinary approaches to skills development, for example by establishing combined study courses or by introducing other domain modules and by promoting interfaculty teaching and research exchanges.

d. Promote the teaching of soft skills, while ensuring that students continue to learn high-level and high quality technical skills.

e. Tackle the skills gap between the skills students acquire at universities and vocational institutions and the skills needed by industry by promoting workplace-based learning, including through internships, in cooperation with education and training institutions, employers, and employers' and workers' organizations.

f. Equip students with the necessary foundational or transferable skills to ensure that they are able to learn throughout their lifetime.

g. Continue to promote international student exchanges in order to widen students' horizons and provide them with enriching experiences abroad.

h. Provide early vocational orientation sessions in order to address entrenched gender stereotypes.

i. Provide continuous training for teaching staff at vocational schools and higher education institutions to ensure that teaching methodologies keep pace with rapid technological change.

4.2.3 For employers' and workers' organizations

a. Raise awareness of the importance of equal career opportunities for men and women, address gender-based discrimination, and, where necessary, take action to make workplaces more gender responsive.

b. Introduce mechanisms that prevent workers from working unduly long working hours over long periods of time and implement measures to address and prevent stress-related health issues.

c. Provide support to platform workers to ensure decent working conditions in the ICT sector.

d. Foster the active engagement of employers' and workers' organizations with regard to developing skills and curricula in VET and in the higher education system, including through sectoral skills bodies.

e. Strengthen cooperation with education and training institutions in order to close skills gaps.

f. Continue to support lifelong learning and promote continuous training in the light of ongoing rapid technological change, for example by establishing job-related educational incentives within companies, giving greater attention to career path planning, and introducing on-the-job learning, inter alia, through job shadowing and job rotation.

g. Promote work-based learning as an integral component of VET programmes and courses at higher education institutions, and ensure high quality workplace learning by strengthening cooperation among industry and education and training institutions.

h. Provide counselling, networking and language training to help migrant ICT specialists settle into their new working and living environments in destination countries.

i. Continue to strengthen social dialogue between governments, employers' and workers' organizations to promote decent work in the ICT sector.

Annex

Table A1 Definition of the ICT sector based on International Standard Industrial Classification (ISIC) Rev.4

ICT manufacturing industries
2610 Manufacture of electronic components and boards
2620 Manufacture of computers and peripheral equipment
2630 Manufacture of communication equipment
2640 Manufacture of consumer electronics
2680 Manufacture of magnetic and optical media
ICT trade industries
4651 Wholesale of computers, computer peripheral equipment and software
4652 Wholesale of electronic and telecommunications equipment and parts
ICT services industries
5820 Software publishing
61 Telecommunications
6110 Wired telecommunications activities
6120 Wireless telecommunications activities
6130 Satellite telecommunications activities
6190 Other telecommunications activities
62 Computer programming, consultancy and related activities
6201 Computer programming activities
6202 Computer consultancy and computer facilities management activities
6209 Other information technology and computer service activities
631 Data processing, hosting and related activities; web portals
6311 Data processing, hosting and related activities
6312 Web portals
951 Repair of computers and communication equipment
9511 Repair of computers and peripheral equipment
9512 Repair of communication equipment

▶ **Table A2 Definition of ICT specialists according to International Standard Classification of Occupations (ISCO) – 08, OECD and Eurostat**

133 Information and Communications Technology services managers
215 Electrotechnology engineers
2152 Electronics engineers
2153 Telecommunications engineers
25 Information and Communications Technology professionals
251 Software and applications developers and analysts
2511 Systems analysts
2512 Software developers
2513 Web and multimedia developers
2514 Applications programmers
2519 Software and applications developers and analysts not elsewhere classified
252 Database and network professionals
2521 Database designers and administrators
2522 Systems administrators
2523 Computer network professionals
2529 Database and network professionals not elsewhere classified
35 Information and communications technicians
351 ICT operations and user support technicians
3511 ICT operations technicians
3512 ICT user support technicians
3513 Computer network and systems technicians
3514 Web technicians
352 Telecommunications and broadcasting technicians
3521 Broadcasting and audiovisual technicians
3522 Telecommunications engineering technicians
742 Electronics and telecommunications installers and repairers
7421 Electronics mechanics and servicers
7422 ICT installers and servicers
2166 Graphic and multimedia designers
2356 Information technology trainers
2434 ICT sales professionals
3114 Electronics engineering technicians

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Canada

▶ **Table A3 Classification of ICT sector occupations, Canada**

North American Industry Classification System (NAICS) Code	ISIC equivalent	ICT Sub-Sector
3333		Commercial and Service Industry Machine Manufacturing
3341	2620	Computer and Peripheral Equipment Manufacturing
3342	2630	Communications Equipment Manufacturing
3343	2640, 2680	Audio and Video Equipment Manufacturing
3344	2610	Semiconductor and other Electronic Component Manufacturing
3345	2680	Navigational, Medical and Control Instruments Manufacturing
4173	4651 and 4652	Computer and Communications Equipment and Supplies, Wholesale distribution
5112	5820	Software Publishers
5171	6110 and 6120	Wired Telecommunications Carrier
5172		Wired Telecommunications Carrier (except satellite)
5174	6130	Satellite Telecommunications
5179	6190	Other Telecommunications
5182	6311	Data Processing, Hosting, and Related Services
5415		Computer Systems Design, and Related Services
8112	951	Electronic and Precision Equipment Repair and Maintenance

Source: Compiled by national consultant

▶ Table A4 Classification of ICT occupations according to the National Occupation Classification (NOC), and the number of workers employed in each ICT occupation, Canada

NOC Code	Occupation Title	Number employed in 2016	
		In absolute numbers	In %
0131	Telecommunication carriers manager	12 900	1
0211	Engineering managers	30 900	2
0213	Computer and information systems managers	69 100	5
0911	Manufacturing mangers	80 500	6
1252	Health information management occupations	19 300	1
2133	Electrical and electronics engineers	34 000	3
2147	Computer engineers (except software engineers and designers)	24 600	2
2171	Information systems analysts and consultants	196 300	15
2172	Database analysts and data administrators	35 500	3
2173	Software engineers and designers	51 800	4
2174	Computer programmers and interactive media developers	151 900	12
2175	Web designers and developers	32 400	2
2241	Electrical and electronics engineering technologists and technicians	31 600	2
2242	Electronic service technicians (household and business equipment)	58 500	4
2243	Industrial instrument technicians and mechanics	15 200	1
2281	Computer network technicians	50 400	4
2282	User support technicians	106 300	8
2283	Information systems testing technicians		
5222	Film and video camera operators		
5223	Graphic arts technicians	46 900	3
5225	Audio and video recording technicians		
5241	Graphic designers and illustrators	84 400	6
6221	Technical sales specialists –wholesale trade	131 700	10
9222	Supervisors, electronics manufacturing	61 800	5
9523	Electronics assemblers, fabricators, inspectors and testers	16 100	1
	Total	**1 342 100**	**100**

Source: Compiled by national consultant

Germany

▶ Table A5 Classification of ICT sector occupations, Germany

Classification of occupations according to the Classification of Economic Activities, issue 2008 (WZ 2008), incorporating NACE Rev. 2 (Statistical classification of economic activities in the European Community)	
WZ 2008 J – Information and Communication	
58	Publishing activities
59	Motion picture, video and television programme production, sound recording and music publishing activities
60	Programming and broadcasting activities
61	Telecommunications
62	Computer programming, consultancy and related activities
63	Information service activities

Source: Compiled by national consultant

▶ Table A6 Classification of ICT occupations according to Classification of Occupations 2010 (KldB 2010) (4-digit level) and No. of workers employed in ICT occupations, Germany

Classification of ICT specialists according to KldB 2010 (4-digit level)	Persons employed, 2018	% share of total No. of ICT specialists subject to social security contributions
2322 Occupations in graphic, communication, and photo design	46 865	3.06
2611 Occupations in mechatronics	67 926	4.44
2612 Occupations in automation and control technology	40 945	2.67
2623 Technical occupations in energy and power plant technology	35 188	2.30
2624 Occupations in renewable energy technology	5 947	0.39
2626 Occupations in installing and servicing electrical cables	27 888	1.82
2630 Occupations in electrical engineering (without specialization)	242 361	15.83
2631 Occupations in information and telecommunication technology	192 871	12.60
2632 Occupations in microsystems technology	8 405	0.55
2633 Occupations in aeronautic, naval, and automotive electronics	10 202	0.67
2638 Occupations in electrical engineering (with specialization, not elsewhere classified)	16 984	1.11
4310 Occupations in computer science (without specialization)	182 542	11.92
4311 Occupations in business informatics	27 573	1.80
4312 Occupations in computer engineering	11 853	0.77
4313 Occupations in bio- and medical informatics	1 285	0.08
4314 Occupations in geoinformatics	1 109	0.07
4315 Occupations in media informatics	13 855	0.91
4319 Managers in computer science	2 508	0.16
4321 Occupations in IT-system analysis	29 379	1.92
4322 Occupations in IT-application consulting	123 706	8.08
4323 Occupations in IT-sales	23 200	1.52
4331 Occupations in IT-network engineering	10 373	0.68
4332 Occupations in IT-coordination	15 851	1.04
4333 Occupations in IT-organization	21 327	1.39
4334 Occupations in IT-system-administration	76 206	4.98
4335 Occupations in database development and administration	6 835	0.45
4336 Occupations in web administration	893	0.06
4338 Occupations in IT-network engineering, IT-coordination, IT-administration and IT-organization (with specialization, not elsewhere classified)	8 846	0.58

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▶ **Table A6 Classification of ICT occupations according to Classification of Occupations 2010 (KldB 2010) (4-digit level) and No. of workers employed in ICT occupations, Germany *(final)***

Classification of ICT specialists according to KldB 2010 (4-digit level)	Persons employed, 2018	% share of total No. of ICT specialists subject to social security contributions
4339 Managers in IT-network engineering, IT-coordination, IT-administration and IT-organization (with specialization, not elsewhere classified)	20 051	1.31
4341 Occupations in software development	186 353	12.17
4342 Occupations in programming	34 453	2.25
4349 Managers in software development and programming	3 573	0.23
5118 Technical occupations in railway, aircraft and ship operation (with specialization, not elsewhere classified)	347	0.02
5123 Technical occupations in air traffic control	515	0.03
6114 Occupations in placing and servicing vending machines	5 516	0.36
8250 Technical occupations in medicine (without specialization)	8 128	0.53
8444 Occupations in IT-application training	2 548	0.17
9452 Cinematographers, camera assistants, and projectionists	3 714	0.24
9453 Technical occupations in video and sound production	12 755	0.83
ICT-specialists subject to social security contributions	1 530 876	100
+ 8.5% self-employed in KldB 2010 group 43 (estimated, on the basis of Bundestag 2018b, data for 2017)	142 213	
Estimated total number of ICT specialists in Germany in 2018	**1 673 089**	

Sources: OECD/Eurostat definition of ICT-specialists, BA (data and ISCO-08 – KldB-2010 conversion table), national consultant calculations

Note: By converting the administrative data on dependent employment available for the KldB-2010 (5-digit level) to the ISCO-08 4-digit level,[1] it is possible to apply the OECD/Eurostat classification to ICT occupations in Germany (see table A1).[2] Assuming that employment subject to social security contributions roughly corresponds to the total number of employees and further assuming that 8.5 per cent of all ICT specialists in Germany are self-employed (Bundestag, 2018b), the total number of ICT specialists in Germany is approximately 1.67 million.

1 A conversion table is available at: statistik.arbeitsagentur.de/Statischer-Content/Grundlagen/Klassifikationen/Klassifikation-der-Berufe/KldB2010/Arbeitshilfen/Umsteigeschluessel/Generische-Publikation/Umsteigeschluessel-KldB2010-ISCO-08
It should be noted that some KldB-2010 occupations at the 5-digit level cannot be assigned unambiguously to a single ISCO-08 occupation at the four-digit level. Some KldB-2010 occupations therefore apply to several ISCO-08 categories (even at the two-digit level).

2 Publicly available Labour Force Survey data and BA data on the employment of ICT specialists is made available in accordance with KldB-2010 parameters.

Table A7 ICT occupations in Germany and skills level requirements

KldB-2010 (4-digit level)	Total (ICT)		Skills level requirements – worker must perform:			
	Persons employed	Share of total (%)	unskilled/semi-skilled tasks	skilled tasks	complex tasks	highly complex tasks
2322 Occupations in graphic, communication, and photo design	46 865	3.06	0.0	9.4	48.8	41.8
2611 Occupations in mechatronics	67 926	4.44	0.0	92.2	5.5	2.2
2612 Occupations in automation and control technology	40 945	2.67	0.0	52.9	25.8	21.3
2623 Technical occupations in energy and power plant technology	35 188	2.30	0.0	32.5	41.8	25.7
2624 Occupations in renewable energy technology	5 947	0.39	0.0	24.3	58.1	17.6
2626 Occupations in installing and servicing electrical cables	27 888	1.82	0.0	96.8	3.1	0.0
2630 Occupations in electrical engineering (without specialization)	242 361	15.83	47.5	13.4	20.9	18.1
2631 Occupations in information and telecommunication technology	192 871	12.60	0.0	73.0	19.8	7.1
2632 Occupations in microsystems technology	8 405	0.55	0.0	56.5	6.5	37.1
2633 Occupations in aeronautic, naval, and automotive electronics	10 202	0.67	0.0	88.1	0.5	11.3
2638 Occupations in electrical engineering (with specialization, not elsewhere classified)	16 984	1.11	0.0	55.2	19.4	25.3
4310 Occupations in computer science (without specialization)	182 542	11.92	0.0	52.1	38.2	9.7
4311 Occupations in business informatics	27 573	1.80	0.0	48.8	33.3	17.9
4312 Occupations in computer engineering	11 853	0.77	0.0	22.9	46.0	31.0
4313 Occupations in bio- and medical informatics	1 285	0.08	0.0	0.0	0.0	100.0
4314 Occupations in geoinformatics	1 109	0.07	0.0	0.0	0.0	100.0
4315 Occupations in media informatics	13 855	0.91	0.0	7.2	86.6	6.2
4319 Managers in computer science	2 508	0.16	0.0	0.0	0.0	100.0
4321 Occupations in IT-system analysis	29 379	1.92	0.0	0.0	0.0	100.0
4322 Occupations in IT-application consulting	123 706	8.08	0.0	0.0	52.9	47.1
4323 Occupations in IT-sales	23 200	1.52	0.0	0.0	100.0	0.0
4331 Occupations in IT-network engineering	10 373	0.68	0.0	0.0	85.8	14.2

KldB-2010 (4-digit level)	Total (ICT)		Skills level requirements – worker must perform:			
	Persons employed	Share of total (%)	unskilled/semi-skilled tasks	skilled tasks	complex tasks	highly complex tasks
4332 Occupations in IT-coordination	15 851	1.04	0.0	0.0	100.0	0.0
4333 Occupations in IT-organization	21 327	1.39	0.0	0.0	100.0	0.0
4334 Occupations in IT-system administration	76 206	4.98	0.0	0.0	100.0	0.0
4335 Occupations in database development and administration	6 835	0.45	0.0	0.0	100.0	0.0
4336 Occupations in web administration	893	0.06	0.0	0.0	100.0	0.0
4338 Occupations in IT-network engineering. IT-coordination. IT-administration and IT-organization (with specialization, not elsewhere classified)	8 846	0.58	0.0	0.0	72.2	27.8
4339 Managers in IT-network engineering, IT-coordination, IT-administration and IT-organization (with specialization, not elsewhere classified)	20 051	1.31	0.0	0.0	0.0	100.0
4341 Occupations in software development	186 353	12.17	0.0	11.7	14.8	73.5
4342 Occupations in programming	34 453	2.25	0.0	0.0	100.0	0.0
4349 Managers in software development and programming	3 573	0.23	0.0	0.0	0.0	100.0
5118 Technical occupations in railway, aircraft and ship operation (with specialization, not elsewhere classified)	347	0.02	0.0	96.8	3.2	0.0
5123 Technical occupations in air traffic control	515	0.03	0.0	0.0	91.1	8.9
6114 Occupations in placing and servicing vending machines	5 516	0.36	0.0	100.0	0.0	0.0
8250 Technical occupations in medicine (without specialization)	8 128	0.53	0.0	6.1	71.1	22.9
8444 Occupations in IT-application training	2 548	0.17	0.0	0.0	0.0	100.0
9452 Cinematographers, camera assistants, and projectionists	3 714	0.24	0.0	54.6	45.4	0.0
9453 Technical occupations in video and sound production	12 755	0.83	0.0	36.0	49.8	14.2
ICT specialists (total) subject to social security contributions	**1 530 876**	**100.00**	**7.5**	**30.8**	**35.7**	**25.9**
All occupations (total) subject to social security contributions			**15.7**	**58.0**	**12.7**	**13.0**

Source: BA, numbers refer to dependent employees subject to social security contributions.

▸ **Table A8 Employment in ICT occupations by gender, Germany**

KldB-2010 (4-digit level)	Total employees (ICT)		Female employees	
	Persons employed	Share of total (%)	No. of women employed	Share of total employees (%)
2322 Occupations in graphic, communication, and photo design	46 865	3.06	23 447	50.0
5118 Technical occupations in railway, aircraft and ship operation (with specialization, not elsewhere classified)	347	0.02	162	46.7
4313 Occupations in bio- and medical informatics	1 285	0.08	438	34.1
6114 Occupations in placing and servicing vending machines	5 516	0.36	1 676	30.4
8444 Occupations in IT-application training	2 548	0.17	768	30.1
4314 Occupations in geoinformatics	1 109	0.07	318	28.7
2632 Occupations in microsystems technology	8 405	0.55	2 398	28.5
4336 Occupations in web administration	893	0.06	246	27.5
4311 Occupations in business informatics	27 573	1.80	7 417	26.9
9453 Technical occupations in video and sound production	12 755	0.83	3 241	25.4
4335 Occupations in database development and administration	6 835	0.45	1 723	25.2
2630 Occupations in electrical engineering (without specialization)	242 361	15.83	60 133	24.8
4315 Occupations in media informatics	13 855	0.91	3 287	23.7
4332 Occupations in IT-coordination	15 851	1.04	3 650	23.0
4323 Occupations in IT-sales	23 200	1.52	5 254	22.6
4333 Occupations in IT-organization	21 327	1.39	4 655	21.8
4322 Occupations in IT-application-consulting	123 706	8.08	26 107	21.1
8250 Technical occupations in medicine (without specialization)	8 128	0.53	1 687	20.8
9452 Cinematographers, camera assistants, and projectionists	3 714	0.24	630	17.0
4310 Occupations in computer science (without specialization)	182 542	11.92	30 069	16.5

KldB-2010 (4-digit level)	Total employees (ICT)		Female employees	
	Persons employed	Share of total (%)	No. of women employed	Share of total employees (%)
4321 Occupations in IT-system-analysis	29 379	1.92	4 003	13.6
4342 Occupations in programming	34 453	2.25	4 633	13.4
4331 Occupations in IT-network engineering	10 373	0.68	1 348	13.0
4341 Occupations in software development	186 353	12.17	23 813	12.8
4319 Managers in computer science	2 508	0.16	313	12.5
2631 Occupations in information and telecommunication technology	192 871	12.60	23 013	11.9
4312 Occupations in computer engineering	11 853	0.77	1 339	11.3
4334 Occupations in IT-system administration	76 206	4.98	8 008	10.5
2624 Occupations in renewable energy technology	5 947	0.39	607	10.2
4339 Managers in IT-network engineering, IT-coordination, IT-administration and IT-organization (with specialization, not elsewhere classified)	20 051	1.31	2 034	10.1
2638 Occupations in electrical engineering (with specialization, not elsewhere classified)	16 984	1.11	1 698	10.0
4349 Managers in software development and programming	3 573	0.23	318	8.9
2611 Occupations in mechatronics	67 926	4.44	5 067	7.5
5123 Technical occupations in air traffic control	515	0.03	35	6.8
2623 Technical occupations in energy and power plant technology	35 188	2.30	2 333	6.6
2612 Occupations in automation and control technology	40 945	2.67	2 708	6.6
2633 Occupations in aeronautic, naval, and automotive electronics	10 202	0.67	474	4.6
2626 Occupations in installing and servicing electrical cables	27 888	1.82	1 081	3.9
ICT specialists (total) subject to social security contributions	**1 530 876**	**100.00**	**261 560**	**17.1**
All occupations (total) subject to social security contributions	**32 870 228**		**15 173 692**	**46.2**

Source: BA, numbers refer to dependent employees subject to social security contributions.

Singapore

▶ Table A9 Classification of ICT sector occupations, Singapore

Singapore: classification of ICT sector occupations
5811 Book publishing 5812 Publishing of directories and mailing lists 5813 Publishing of news, journals and periodicals 5819 Other publishing activities
5820 Software publishing
5911 Motion picture, video, television and other programme production activities 5912 Motion picture, video, television and other programme post-production activities 5913 Motion picture, video, television and other programme distribution activities 5914 Motion picture projection activities 5920 Sound recording and music publishing activities
6010 Radio programme production and broadcasting 6020 Television programming and broadcasting
6101 Telecommunications network operation 6109 Other telecommunications activities
6201 Computer programming activities 6202 Computer consultancy and computer facilities management activities 6209 Other information technology and computer service activities
6311 Data analytics, processing, hosting and related activities 6312 Web portals 6390 Other information service activities

Source: OECD[3] and Statistics Department of Singapore

3 For further information, see: Information economy sector definitions based on the International Standard Industry Classification (ISIC 4) OECD DSTI/ICCP/IIS(2006)2/FINAL. Available at: www.oecd.org/sti/38217340.pdf

▶ **Table A10 Classification of ICT specialists, Singapore**

Singapore Standard Occupational Classification (SSOC) 2015 Code	Description
1330	Information and communications technology service managers
2152	Electronics engineers
2153	Telecommunications engineers
2166	Graphic and multimedia designers and artists
2433	Specialized goods sales professionals
2511	Systems analysts
2512	Software, web and multimedia developers
2514	Applications and systems programmers
2515	Information technology testing and quality assurance professionals
2516	Information technology project managers
2519	Software and applications developers and analysts not elsewhere classified
2521	Database designers and administrators
2522	Network, servers and computer systems administrators
2523	Computer network and infrastructure professionals
2524	Information technology security specialists
2529	Database and network professionals not elsewhere classified
3114	Electronics engineering technicians
3511	Computer systems operators
3512	Computer technicians
3514	Website administrators
3521	Broadcasting technicians and audio-visual operators
3522	Telecommunications engineering technicians
3523	Telecommunications equipment operators
3620	Extracurricular instructors
7421	Electronics mechanics and servicers
7422	Information and communications technology installers and servicers

Source: Compiled by national consultant

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Research interviews and list of interviewees

In addition to a literature review and the analysis of data provided by national statistical offices, information was obtained in interviews with government agencies, workers' and employers' organizations, educational and training institutions, private companies and academics in the four target countries. Those interviews provided crucial input for this report. The interviewees were asked questions about general trends in the ICT sector and the labour market, skills development, labour migration and cooperation with other relevant stakeholders. The questions asked varied according to the expertise of each interviewee.

Information obtained during the interviews were used to corroborate the findings of previous studies and to address knowledge gaps. Research interviews were conducted with individuals from the entities listed in table A11.

Table A11 List of interviewees

Canada
Bell Canada
British Columbia Institute of Technology (BCIT)
Canadian Employers Council (CEC)
Canadian Labour Congress (CLC)
Canadian Union of Public Employees
Employment and Social Development Canada (ESDC)
Federally Regulated Employers – Transportation and Communications (FETCO)
HeadCheck Health
Immigration, Refugees and Citizenship Canada (IRCC)
Innovation, Science and Economic Development Canada (ISED)
Labour Market Information Council
MaRS
Microsoft Canada
Modis Canada
Ontario Ministry of Colleges and Universities
Ottawa Employment Hub, Algonquin College
University of Ottawa (Prof. David Gray)
Radical I/O Technology
The Research Universities' Council of British Columbia (RUCBC)
The Vancouver Economic Commission
Semios
World Education Services

▶ Table A11 List of interviewees *(cont.)*

China
All-China Federation of Trade Unions (ACFTU)
Beijing Information Technology College
China Enterprise Confederation/China Enterprise Directors Association (CEC/CEDA)
Ministry of Industry and Information Technology China Center for Information Industry Development
Garage Café
iDreamsky Technology
International Exchange Center of Aerospace Science and Technology
Micron Technology, Inc.
Ministry of Education
Ministry of Human Resources and Social Security (MOHRSS)
Robosense
Beijing Institute of Technology - Shenzhen Graduate School
Shenzhen Polytechnic
SOUL元AR人
TAOLE
Tsinghua University
Zhaopin Ltd.
Germany
Academic Work/Academic Work Academy
acatech (Deutsche Akademie der Technikwissenschaften) (National Academy of Science and Engineering)
Wissenschaftszentrum Berlin für Sozialforschung (WZB) (Berlin Social Science Center) (Prof. Martin Krzywdzinski)
Beuth Hochschule, Berlin (Prof. Martin von Löwis)
Bitkom e.V. – Federal Association for Information Technology, Telecommunications and New Media
Industrie- und Handelskammer (IHK) (Chamber of Commerce and Industry), Munich
Bundesvereinigung der Deutschen Arbeitgeberverbände (BDA) (Confederation of German Employers' Associations)
Deutsche Telekom
Bundesagentur für Arbeit (BA) (Federal Employment Agency)
Bundesinstitut für Berufsbildung (BiBB) (Federal Institute for Vocational Education and Training)
Bundesministerium für Arbeit und Soziales (BMAS) (Federal Ministry of Labour and Social Affairs)
Fraunhofer Academy
Hays PLC.
Humboldt University of Berlin (Prof. Niels Pinkwart)

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▶ Table A11 List of interviewees *(final)*

IG Metall
Infineon Technologies AG
Institut für Arbeitsmarkt- und Berufsforschung (IAB) (Institute for Employment Research) (Florian Lehmer, Dr. Gerd Zika)
Anstalt für Kommunale Datenverarbeitung in Bayern (AKDB) (Institute for Municipal Data Processing in Bavaria)
IZA Institute of Labor Economics (Dr. Terry Gregory)
Ludwig-Maximilians University, Munich (Prof. Thomas Hess)
Modis Germany
ReDI School of Digital Integration
Scout24
Technische Universität München (TUM) (Technical University of Munich) (Prof. Hans-Joachim Bungartz)
Verein Deutscher Ingenieure (VDI) (The Association of German Engineers)
Hochschule für Angewandte Wissenschaften München (MUAS) (Munich University of Applied Sciences) (Klaus Kreulich, Prof. Veronika Thurner)
Vereinte Dienstleistungsgewerkschaft (ver.di) (German United Services Trade Union)
Singapore
AI Singapore (Prof. Leong Tze Yun)
EMA Partners
Ensign Infosecurity
Hewlett Packard Enterprise Singapore
Infocomm Media Development Authority (IMDA)
Institute for Adult Learning (Prof. Johnny Sung)
iTrain Asia Pte. Ltd.
Liquid Group Pte. Ltd.
National Trades Union Congress (NTUC)
National University of Singapore (NUS) (Prof. Tan Eng Chye)
Overdrive IOT Pte. Ltd.
Singapore Institute of Technology (SIT) (Prof. Yaacob Ibrahim)
Singapore Polytechnic
SGTech
Taiger
Tech Talent AssemBly (TTAB)
Tech Skills Accelerator (TeSA) ICT Sector Committee
Wonderlabs
Workforce Singapore (WSG)
Xcellink Pte. Ltd.

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