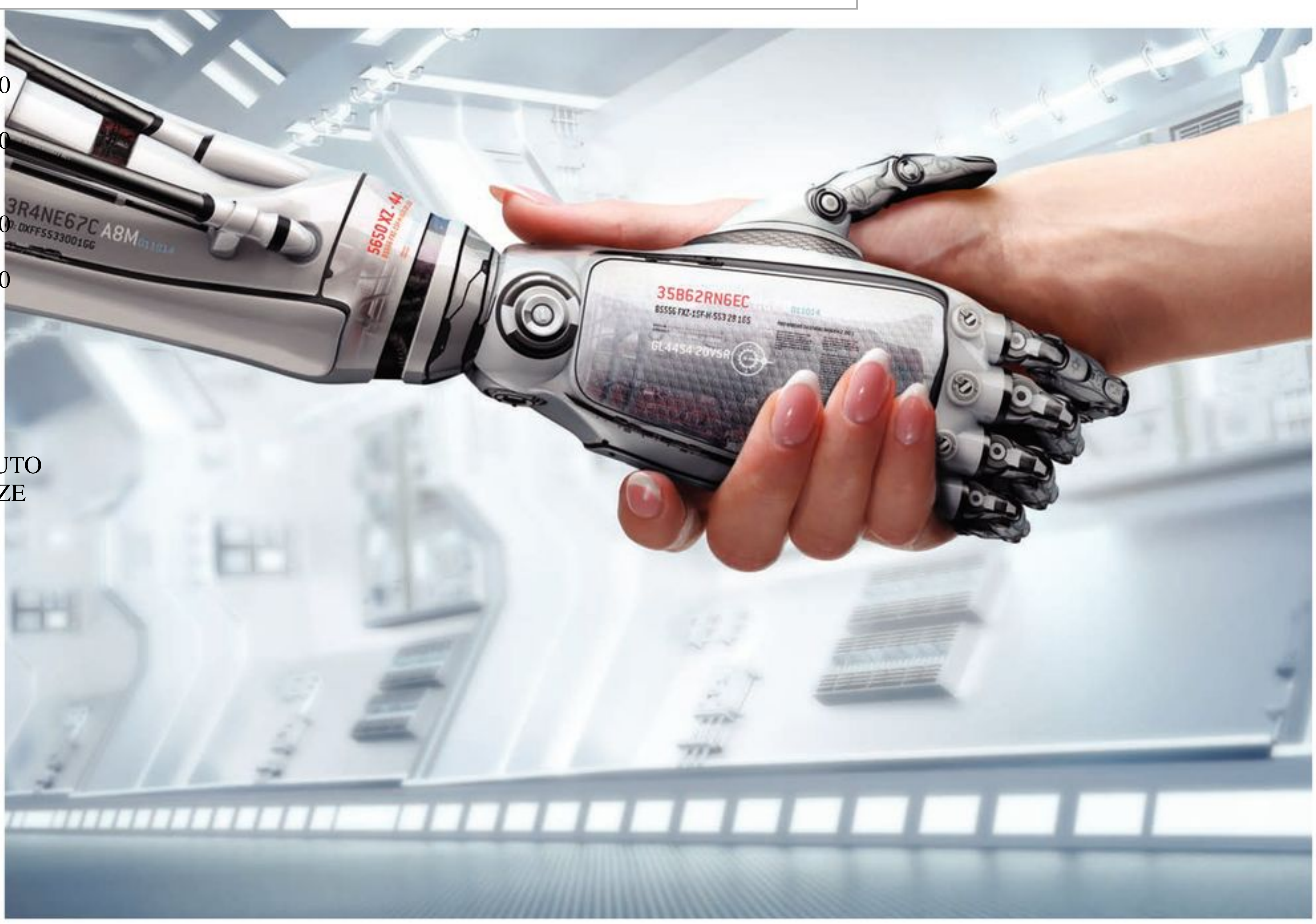
The Next Production Revolution

IMPLICATIONS FOR GOVERNMENTS AND BUSINESS



OECD

The Next Production Revolution

IMPLICATIONS FOR GOVERNMENTS AND BUSINESS

OECD
BETTER POLICIES FOR BETTER LIVES

This report, except Chapters 2 and 5, was declassified by the OECD Committee for Scientific and Technological Policy (CSTP) on 17 April 2017 by written procedure. Chapter 2 was declassified by the Committee for Digital Economy Policy on 12 February 2017 by written procedure. Chapter 5 was declassified by the Environment Policy Committee on 30 January 2017. The report was prepared for publication by the OECD Secretariat. The opinions expressed and arguments employed herein do not necessarily reflect the official views of OECD member countries.

This document, as well as any data and any map included herein, are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Please cite this publication as:
OECD (2017), *The Next Production Revolution: Implications for Governments and Business*, OECD Publishing, Paris.
http://dx.doi.org/10.1787/9789264271036-en

ISBN 978-92-64-27099-2 (print)
ISBN 978-92-64-27103-6 (PDF)
ISBN 978-92-64-27115-9 (ePub)

Revised version, May 2017.
Details of revisions available at: *www.oecd.org/about/publishing/Corrigendum-TheNextProductionRevolution.pdf*.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Photo credits: Cover © Willyam Bradberry/Shutterstock.com.

Corrigenda to OECD publications may be found on line at: *www.oecd.org/about/publishing/corrigenda.htm*.

Preface

On an almost daily basis, we hear of technological breakthroughs ranging from artificial intelligence and 3D printing, to self-driving vehicles. We are entering a world of "digital manufacturing" and "the fourth industrial revolution". It is a pleasure, therefore, to present *The Next Production Revolution: Implications for Governments and Business*, an in-depth OECD assessment of the medium-term economic and policy implications of new and emerging production technologies.

How production might evolve has far-reaching consequences for productivity, employment, skills, income distribution, trade, well-being and the environment. And the policy implications of the next production revolution are far-reaching. Indeed, it is difficult to mention a major area of policy that will be unaffected. From research and education, to data security and infrastructure, the future of production is central to many aspects of the OECD's work.

New production technologies are reshaping the availability and nature of work. It is therefore important that strategies for inclusion understand this process. In fact, new production technologies tie together the critically important themes of productivity and inclusiveness, one of the key concerns of the OECD. As challenges related to population ageing multiply, OECD countries will need the productivity gains that these technologies can deliver. Most importantly, workers also need to be equipped to use these technologies, and policies need to be designed so that economies and societies cope well with the adjustments that these technologies entail.

From this year onwards, the OECD is increasingly focusing upon the digital transformation of the economy and society. This report illustrates just how pervasive and important digital technology is to production and how much more impact digital technology could have if its diffusion was more widespread. This is true even in fields that we do not usually think of as digital, such as industrial biotechnology and new materials.

New production technologies will also affect how we deal with climate change and the natural environment. Positive environmental effects could take many exciting forms, from industrial printing of products using bio-friendly materials, to writing genetic code that allows micro-organisms to make fuels, to drastically reducing waste in zero-defect factories.

The next production revolution is also relevant to the issue of trust in government. Public resistance to new technologies is linked to diminished trust in scientific and regulatory authorities. When the economic or social implications of certain new technologies are disruptive, such trust is particularly important. In this regard, this report offers a sober reflection on some of the hyperbole associated with new production technologies.

A further highlight of this report is the extensive assessment of developments in China. The OECD has worked closely with China on the subject of the next production revolution during China's G20 Presidency. While China has many challenges to overcome, its achievements will have global ramifications.

Lastly, in keeping with the OECD's work on New Approaches to Economic Challenges (NAEC), multidisciplinarity remains essential in grasping today's real-world complexities. This report, therefore, lays out the emerging features of production across many technologies, from multiple policy standpoints and using different types of evidence and analysis. The more governments understand about how production is developing, the better positioned they will be to tackle emerging challenges and achieve economic, social and environmental goals.

Angel Gurría
Secretary-General of the OECD

Foreword

At the start of 2015 the OECD began work on a two-year project entitled Enabling the Next Production Revolution. The work set out to better understand the economic and policy implications of a set of technologies that are likely to significantly affect production over the medium term.

This work commenced with financial support from the Secretary-General's Central Priority Fund. The project greatly benefitted from voluntary contributions from the governments of Australia and the United Kingdom. Particular thanks are due to the government of Norway, whose support helped to widen the project's scope. Thanks are likewise due to the government of Sweden, particularly the Ministry for Enterprise and Innovation and the national innovation agency, Vinnova, for co-organising and hosting a major conference on the themes in this report, titled Smart Industry: Enabling the Next Production Revolution. The conference, held in Stockholm in November 2016, helped to discuss and refine analyses and policy ideas with policymakers, practitioners and academics. The conference was filmed, and the proceedings can be viewed at www.vinnova.se/en/misc/Smart_Industry_Conference/.

Owing to the cross-cutting character of the work on the next production revolution, the chapters of this publication were discussed and declassified by various OECD Committees, including the Committee for Scientific and Technological Policy (which had oversight responsibility for the project); the Committee for Industry, Innovation and Entrepreneurship, the Committee for Digital Economy Policy and the Environment Policy Committee. The comments and inputs formulated by delegates to these OECD official bodies are gratefully acknowledged. Within the OECD Secretariat, the project was led by the OECD's Directorate for Science, Technology and Innovation. A project interim report containing early policy messages was discussed by the OECD Executive Committee and OECD Council and was presented at the OECD's Ministerial Council Meeting of June 2016.

As this report describes, much policy-relevant research on the changing nature of production remains to be done. Further information on OECD work on this subject will be posted at http://oe.cd/npr-industry. A number of issues raised in this report in connection with digital technologies will also be examined during 2017 and 2018, with new data, in an OECD project titled Going Digital: Making the Transformation Work for Growth and Well-being. *Updated information on this project can be found at www.oecd.org/sti/goingdigital.htm.*

Acknowledgements

This publication was edited by Alistair Nolan from the OECD's Directorate for Science Technology and Innovation. Alistair Nolan also wrote Chapter 1 ("The next production revolution: Key issues and policy proposals").

Thanks are expressed to Luis Agosto Alcorta, Adot Killmeyer-Oleche and Ayumi Fujino from the United Nations Industrial Development Organisation (UNIDO), for inputs on developing countries for Chapter 1.

Christian Reimsbach-Kounatze, from the OECD's Directorate for Science Technology and Innovation, wrote Chapter 2 ("Benefits and challenges of digitalising production").

Thanks are expressed to Robert Cohen, of the Economic Strategy Institute, for case study material provided for Chapter 2.

Chapter 3 ("Bioproduction and the bioeconomy") was prepared by staff from the OECD's Directorate for Science Technology and Innovation.

Steffi Friedrichs, from the OECD's Directorate for Science Technology and Innovation, wrote Chapter 4 ("Tapping nanotechnology's potential to shape the next production revolution").

Chapter 5 ("3D printing and its environmental implications") was authored by Jeremy Faludi, Principal, Faludi Design, University of California, Berkeley and Minneapolis College of Art and Design, with Natasha Cline-Thomas and Shardul Agrawala from the OECD's Environment Directorate. The authors of Chapter 5 would also like to thank Peter Börkey, Andrew Prag, Matthias Kimmel and Elisabetta Cornago for their substantive and editorial contributions to this chapter.

Chapter 6 ("Revolutionising product design and performance with materials innovation") was written by David L. McDowell, Regents' Professor and Carter N. Paden, Jr. Distinguished Chair in Metals Processing, and Executive Director, Institute for Materials, Georgia Institute of Technology.

Chapter 7 ("The next production revolution and institutions for technology diffusion") was authored by Philip Shapira, Manchester Institute of Innovation Research, Alliance Manchester Business School, University of Manchester, and Jan Youtie, Enterprise Innovation Institute, Georgia Institute of Technology.

Chapter 8 ("Public acceptance and emerging production technologies") was written by David Winickoff from the OECD's Directorate for Science Technology and Innovation.

Chapter 9 ("The role of foresight in shaping the next production revolution") was authored by Attila Havas, from the Hungarian Academy of Sciences, and Matthias Weber, from the Austrian Institute of Technology. Extensive input to this chapter was also provided by Michael Keenan from the OECD's Directorate for Science Technology and Innovation. Duncan Cass-Beggs and Joshua Polchar, from the OECD's Strategic Foresight Unit, kindly commented on this chapter.

Chapter 10 ("An international review of emerging manufacturing R&D priorities and policies for the next production revolution") was authored by Dr Eoin O'Sullivan, Director, Centre for Science, Technology & Innovation Policy (CSTI), Institute for Manufacturing (IfM), University of Cambridge, and Dr Carlos López-Gómez Head, Policy Links Unit, Institute for Manufacturing (IfM), Education and Consulting Services, University of Cambridge.

Chapter 11 ("The rise of advanced manufacturing institutes in the United States") was written by William B. Bonvillian, Lecturer at MIT, and the former Director of MIT's Washington Office.

Chapter 12 ("China and the next production revolution") was authored by Qian Dai, Programme Officer, Department of International Cooperation, Ministry of Science and Technology of China, and Consultant with the OECD's Directorate for Science, Technology and Innovation.

Thanks are expressed for inputs to Chapter 12 provided by Wei Jigang, a research fellow at China's Development Research Center of the State Council (DRC). Dr Zhao Wenchang, Director-General of the DRC's Industrial Economy Research Department, kindly provided comments on this chapter. Thanks are expressed to Sylvia Schwaag Serger, Adjunct Professor, and Executive Director, International Strategy and Networks, Vinnova, for observations on Chapter 12. Antonio Fanelli and Fei Zheng, from the OECD's Global Relations Service, also provided substantive input and statistical support for this chapter. Thanks are likewise due to Georg Stieler, of Stieler Enterprise Management Consulting (Shanghai) Co., Ltd., for his insights on data and indicators of technology use in Chinese firms.

Comments on the development of intellectual property rights were kindly provided by Alexandra Neri, Partner, IP/TMT Department, Herbert Smith Freehills Paris LLP, and Brian Kahin, Senior Fellow at the Computer & Communications Industry Association and Digital Economy Fellow, OECD Directorate for Science, Technology and Innovation. Robert D. Atkinson, President, Information Technology and Innovation Foundation, kindly provided useful materials at various points during the project.

Many OECD staff contributed to this work. Alistair Nolan managed the project, under the guidance of Dominique Guellec, Head of the Science and Technology Policy Division. Dominique Guellec provided substantive input to all chapters in this report and authored the box on intellectual property in Chapter 1. Andrew Wyckoff, Director, Directorate for Science, Technology and Innovation, and Dirk Pilat, Deputy-Director, provided comments and guidance throughout. This publication also draws on the research and observations of other OECD colleagues, including (in alphabetical order): Koen de Backer, Sarah Box, Stuart Elliott (now with the US National Academy of Sciences), Stéphanie Jamet, Nick Johnstone, Carlo Menon and Mariagrazia Squicciarini. During an internship with the OECD, Nicolas Trausch provided excellent support in reviewing research on automation and employment.

Thanks are gratefully offered to the many counterparts in Sweden, particularly at the Ministry for Enterprise and Innovation and the national innovation agency, Vinnova, who co-organised and generously hosted the November 2016 conference Smart Industry: Enabling the Next Production Revolution. In alphabetical order, these include: Erik Fahlbeck, Johan Harvard, Marianne Löfgren, Göran Marklund, Sylvia Schwaag Serger, Jennie Sölving and Karin Stridh.

Catherine Rowles-Holm copy-edited the text and Janine Treves provided support with overall presentation. Beatrice Jeffries gave secretarial support throughout the project. Angela Gosmann prepared the final manuscript for publication and assisted in copy-editing. Blandine Serve and Peter Horvát provided statistical support.

Table of contents

Part II

Cross-cutting themes

Tables

Figures

Follow OECD Publications on:

http://twitter.com/OECD_Pubs

http://www.facebook.com/OECDPublications

http://www.linkedin.com/groups/OECD-Publications-4645871

http://www.youtube.com/oecdilibrary

http://www.oecd.org/oecddirect/

This book has...

StatLinks

A service that delivers Excel® files from the printed page!

Look for the *StatLinks* at the bottom of the tables or graphs in this book. To download the matching Excel® spreadsheet, just type the link into your Internet browser, starting with the *http://dx.doi.org* prefix, or click on the link from the e-book edition.

Executive summary

The next production revolution will occur because of a confluence of technologies. These range from a variety of digital technologies (e.g. 3D printing, the Internet of Things, advanced robotics) and new materials (e.g. bio- or nano-based) to new processes (e.g. data-driven production, artificial intelligence, synthetic biology). This report examines the economic and policy ramifications of a set of technologies likely to be important for production over the near term (to around 2030). As these technologies transform production, they will have far-reaching consequences for productivity, employment, skills, income distribution, trade, well-being and the environment.

Productivity and labour market changes

New production technologies will play important roles in determining the availability and nature of work. Part of a strategy for coping with rising shares of high- and low-wage jobs must involve the growth of technology-intensive production work. Technological development will inevitably disrupt today's industries, and incumbent firms will be challenged as new technologies redefine the terms of competitive success. The precise pace and scale of future adjustments are unknown. But resilience and prosperity will be more likely in countries with forward-looking policies, better functioning institutions, better educated and informed citizens, and critical technological capabilities in a number of sectors.

Command over new production technologies also promises greener production, safer jobs (with some hazardous work performed by robots), new and more customised goods and services, and faster productivity growth. Indeed, the technologies considered in this report, from information and communication technologies and robots to new materials, have more to contribute to productivity than they currently do. Often, their use is predominantly in larger firms. And even in those firms, many potential applications are underused.

Compared to earlier industrial revolutions, induced by steam and electrification, the creation and international spread of inventions that can transform production will occur quickly. But it could take considerable time for new technologies, once invented, to diffuse throughout the economy and for their productivity effects to be fully realised. The past has seen unrealistic enthusiasm regarding timelines for the delivery of important production technologies.

While new technologies will create jobs through a number of channels, and productivity-raising technologies will benefit the economy overall, the associated adjustments could be significant. Hardship could affect many if labour displacement were to occur in a major sector, or in many sectors simultaneously. Policy makers need to monitor and actively manage the adjustments, e.g. through forward-looking policies on skills, labour mobility and regional development.

OECD (Organisation for Economic Co-operation and Development) (2017), *ICT Access and Use by Businesses database*, *http://stats.oecd.org/index.aspx?DatasetCode=ICT_BUS* (accessed in March 2017).

OECD (2016a), "ICTs and jobs: Complements or substitutes?", *OECD Digital Economy Papers*, No. 259, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5jlwnklzplhg-en*.

OECD (2016b), *Nanomaterials in Waste Streams: Current Knowledge on Risks and Impacts*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264249752-en*.

OECD (2015a), "Enabling the next production revolution", report prepared for the conference Shaping the Strategy for Tomorrow's Production, Copenhagen, 27 February.

OECD (2015b), *Data-Driven Innovation: Big Data for Growth and Well-Being*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264229358-en*.

OECD (2015c), *The Future of Productivity*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264248533-en*.

OECD (2015d), "Share of countries in nanotechnology patents, 2010-13", *OECD Key Nanotech Indicators*, database, *www.oecd.org/sti/sci-tech/9-Share-of-countries-in-nanotech-patents-2010-13-2015.xls*.

OECD (2015e), *Digital Security Risk Management for Economic and Social Prosperity: OECD Recommendation and Companion Document*, OECD, Paris, *www.oecd.org/sti/ieconomy/digital-security-risk-management.pdf*.

OECD (2014), *Measuring the Digital Economy: A New Perspective*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264221796-en*.

OECD (2013), "Interconnected economies: Benefiting from global value chains", OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264189560-en*.

Packer, J. (2008), *Mobility without Mayhem: Safety, Cars, and Citizenship*, Duke University Press, Durham, NC.

PEW Foundation (2014), "AI, Robotics and the Future of Jobs", *www.pewinternet.org/2014/08/06/future-of-jobs/*.

Philp, J.C. (2015), "Balancing the bioeconomy: supporting biofuels and bio-based materials in public policy", *Energy & Environmental Science*, Vol. 8, pp. 3063-3068.

Pidgeon, N.F., R.E. Kasperson and P. Slovic (eds.) (2003), *The Social Amplification of Risk*, Cambridge University Press, Cambridge, United Kingdom.

Piketty, T. (2014), *Capital in the Twenty-First Century*, Harvard University Press, Cambridge, MA and London.

Pollack, M.A. and G.C. Shaffer (2009), *When Cooperation Fails: The International Law and Politics of Genetically Modified Foods*, Oxford University Press.

PwC (PricewaterhouseCoopers (2015), "Companies in China see five-fold rise in average detected information security incidents in 2015", pwchk.com, *www.hk-lawyer.org/content/chinese-companies-see-five-fold-rise-average-detected-information-security-incidents-2015*.

Ren, M. (2014), "飞机钛合金起落架可 3D 打印" [3D printing for titanium alloy landing gear of aircraft], *Beijing Daily*, 9 January, *http://tech.hexun.com/2014-01-09/161273352.html*.

Ren, S. (2016), "教育部机器人学中小学课程教学指南专家论证会在京召开" [Expert assessment on robotics education in primary and middle school held in Beijing], *Beijing Times*, 22 January, *http://epaper.jinghua.cn/html/2016-01/22/content_275548.htm*.

Rigby, M. (2015), "Future-proofing UK manufacturing: Current investment trends and future opportunities in robotic automation", Barclays, *www.barclayscorporate.com/content/dam/corppublic/corporate/Documents/research/automation-report.pdf*.

Robinson, L. and K. McMahon (2016), "TMS launches materials data infrastructure study", *JOM*, Vol. 68, Issue 8, pp. 2014-2016.

Rotman, D. (2013), "How technology is destroying jobs", *MIT Technology Review*, June, *www.technologyreview.com/s/515926/how-technology-is-destroying-jobs/*.

Shen, Z. (2015), "中国国产工业机器人同比增长 77%" [Domestic robot production increases by 77%], *Economic Daily*, 13 July, *http://tech.ce.cn/news/201507/13/t20150713_5913227.shtml*.

Shotter, J. and L. Whipp (2016), "Robot revolution helps Adidas bring shoemaking back to Germany", *Financial Times*, 8 June, *www.ft.com/content/7eaffc5a-289c-11e6-8b18-91555f2f4fde#comments*.

Sirkin, H.L., M. Zinser and J. Rose (2014), "The shifting economics of global manufacturing", *BCG Perspectives*, *www.bcgperspectives.com/content/articles/lean_manufacturing_globalization_shifting_economics_global_manufacturing/*.

Spitz-Oener, A. (2006), "Technical change, job tasks, and rising educational demands: Looking outside the wage structure", *Journal of Labor Economics*, Vol. 24, No. 2, pp. 235-270, *www.jstor.org/stable/10.1086/499972*.

Stewart, I., D. Debapratim and A. Cole (2014), "Technology and people: The great job-creating machine", Deloitte, *www2.deloitte.com/uk/en/pages/finance/articles/technology-and-people.html*.

Summers, L.H. (2014), "On the economic challenge of the future: Jobs", *The Wall Street Journal*, 7 July, *www.wsj.com/articles/lawrence-h-summers-on-the-economic-challenge-of-the-future-jobs-1404762501*.

Tassey, G. (2014), "Competing in advanced manufacturing: The need for improved growth models and policies", *Journal of Economic Perspectives*, Vol. 28, No. 1, pp. 27-48.

Teresko, J. (2008), "Designing the next materials revolution", IndustryWeek.com, *www.industryweek.com/none/designing-next-materials-revolution*.

The Economist (2011), "Are ATMs stealing jobs?", *The Economist*, 15 June, *www.economist.com/blogs/democracyinamerica/2011/06/technology-and-unemployment*.

The Economist (2015), "New materials for manufacturing", Technology Quarterly, *The Economist*, 12 May, *www.economist.com/blogs/democracyinamerica/2011/06/technology-and-unemployment*.

Trehan, B. (2003), "Productivity shocks and the unemployment rate", *Federal Reserve Bank of San Francisco Economic Review*, pp. 13-27, *www.frbsf.org/economic-research/files/article2.pdf*.

Vodafone (2015), "M2M Barometer 2015 report", Vodafone, *http://m2m-mktg.vodafone.com/barometer2015*.

Watson, R.R. and V.R. Preedy (2016), *Genetically Modified Organisms in Food: Production, Safety, Regulation and Public Health*, Elsevier Science, Amsterdam, *http://uclibs.org/PID/277991*.

Weilerstein, P. (2014), "NCIIA: Students as the vanguard in a geographically dispersed approach to stimulating science and technology innovation", in J. Engel (ed.), *Global Clusters of Innovation: Entrepreneurial Engines of Economic Growth around the World*, pp. 359-377, Edward Elgar, Cheltenham.

Weiss, M. et al. (2012), "A review of the environmental impacts of bio-based materials", *Journal of Industrial Ecology*, Vol. 16, pp. S169-S181.

Winner, L. (1986), *The Whale and the Reactor: A Search for Limits in an Age of High Technology*, University of Chicago Press.

World Intellectual Property Organization (2015), "World intellectual property report: Breakthrough innovation and economic growth", World Intellectual Property Organization, Geneva, *www.wipo.int/edocs/pubdocs/en/wipo_pub_944_2015.pdf*.

ZEW-IKT (2015), "Industrie 4.0: Digitale (R)Evolution der Wirtschaft" [Industry 4.0: Digital (r)evolution of the economy], ZEW, Mannheim, *http://ftp.zew.de/pub/zew-docs/div/IKTRep/IKT_Report_2015.pdf*.

PART I

Key emerging technologies

The Next Production Revolution
Implications for Governments and Business

PART I

Chapter 2

Benefits and challenges of digitalising production

by
Christian Reimsbach-Kounatze
Directorate for Science, Technology and Innovation, OECD

This chapter examines how new information and communication technology (ICT) applications – in particular big-data analytics, cloud computing and the Internet of Things (IoT) – enable novel production and organisational processes, and business models, mainly in industrial sectors. The chapter focuses on the productivity implications of new ICT applications in early adopting firms in a number of industries (including automotive and aerospace) but also in traditional sectors such as agriculture. An assessment is provided of policy settings needed to realise the potential productivity and other benefits of digital technologies in production, while mitigating a number of associated risks.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Introduction

Digitalisation of the economy and society is progressing rapidly, especially in developed countries. Today, three out of four inhabitants in the OECD area have access to mobile wireless broadband, and up to 95% of all businesses are connected to the Internet. Three-quarters of businesses have an online presence and almost as many engage in e-commerce (OECD, 2015a; 2015b).

Industrial production is undergoing a transformation driven by the conjunction of the increasing interconnection of machines, inventories and goods delivered via the IoT, the capabilities of software embedded in machines, analysis of the large volumes of digital data ("big data") generated by sensors, and the ubiquitous availability of computing power via cloud computing. The resulting transformation has been described by some as "Industry 4.0" (Jasperneite, 2012), the "Industrial Internet" (Bruner, 2013), and "network manufacturing" (Economist Intelligence Unit, 2014). The potential economic benefits of new digital technologies are large. For example, available estimates suggest that the IoT could contribute USD 10 trillion to USD 15 trillion to global gross domestic product (GDP) over the next 20 years (Evans and Anninziata, 2012).

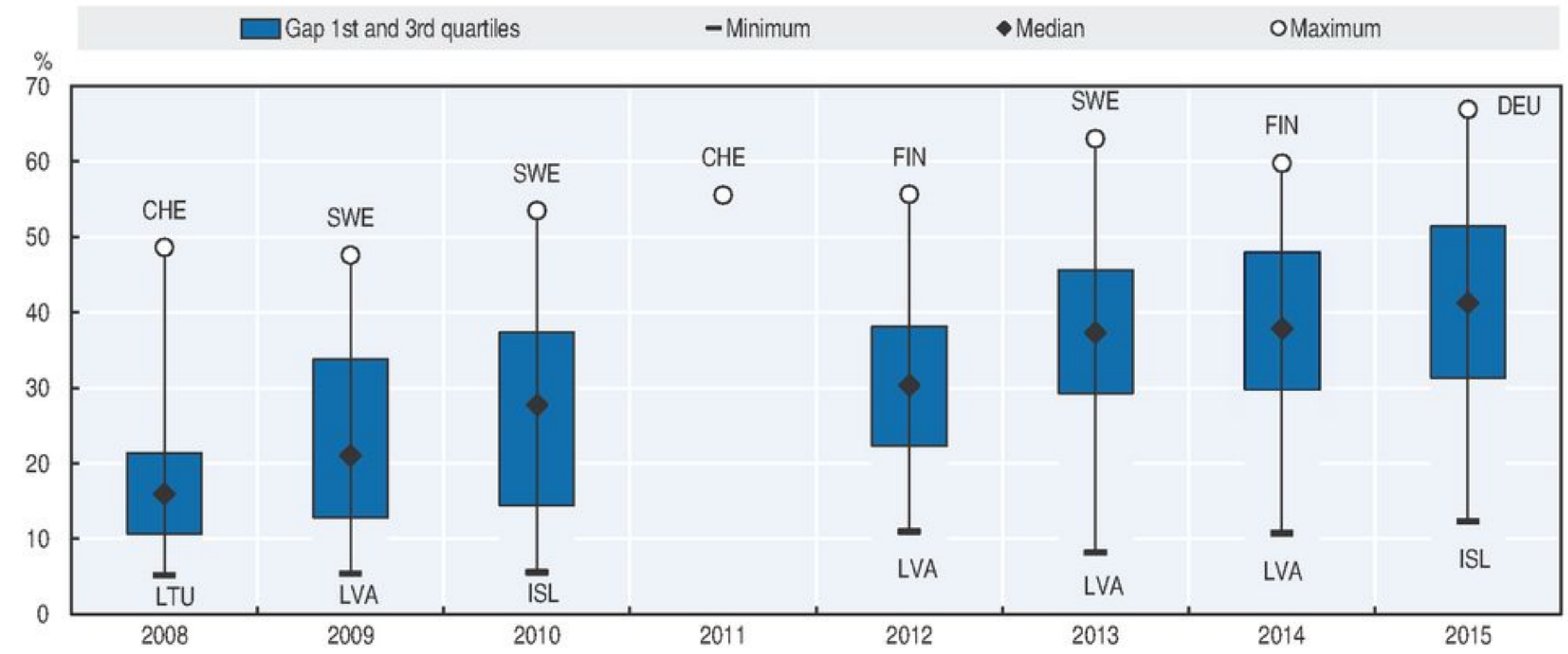
This chapter examines how the conjunction of new digital technologies – in particular big-data analytics, cloud computing and the IoT – enable more customisable goods and services via new production and organisational processes, as well as new business models, mainly in industrial sectors. Based in part on commissioned case study materials, the chapter focuses on the productivity implications of digital technologies in early-adopting firms in a number of industries (including automotive and aerospace) as well as in traditional sectors such as agriculture. It discusses steps that can be taken by traditional firms to successfully transition to digital business models.

Policy suggestions are described which address the main challenges in digitalising industrial production, including: expanding access to data and critical ICT infrastructures and applications; improving interoperability and supporting the development of standards; using existing frameworks – and where necessary refining these – to reduce a range of emerging uncertainties (related e.g. to liability in the context of automation and ownership in an environment where intangible assets such as data can be critical to value creation); reducing risks in connection with digital security and privacy; and fostering competition in new digital contexts. Underpinning all of the above, the chapter likewise points to the need to develop the skills required for the next production revolution.

Adopting advanced ICTs in production

In manufacturing and agriculture, ICTs are transforming production, as businesses are using advanced ICTs such as enterprise resource planning (ERP) and supply chain management (SCM) software to significantly raise productivity.[1] And the use of such software is growing rapidly. In 2015, for example, in the Netherlands, Finland and Sweden, more than 60% of all manufacturing firms used ERP software. By comparison, in 2009, only around 40% of manufacturing firms used ERP software in the Netherlands and Finland, and 50% did so in Sweden. And in Germany, already 70% of manufacturers used ERP software in 2015, compared with some 40% in 2009 (Figure 2.1). In contrast, only 40% of all businesses (across all sectors) in these respective countries used ERP software, with the exception of Germany, where the share was 60% in 2015.

Figure 2.1. **Share of manufacturing firms using ERP software, 2008-15**



Note: This figure does not include data for 2011 except for Switzerland. It includes data for Austria, Belgium (except 2008-09,2014-15), Canada (except 2008-10, 2014-15), Czech Republic, Denmark (except 2008-09), Estonia, Finland (except 2008), France (except 2008), Germany (except 2008), Greece (except 2009-14), Hungary, Iceland (except 2008-09), Ireland (except 2008), Italy (except 2008), Korea (except 2008-10), Latvia (except 2008), Lithuania, Luxembourg (except 2008-09), the Netherlands (except 2008), Norway, Poland (except 2009), Portugal (except 2008), Slovak Republic, Slovenia, Spain (except 2008), Sweden (except 2008), Switzerland (except 2009-10, 2012-2015), Turkey (except 2008-09, 2012-15) and the United Kingdom (except 2008).

Source: Based on OECD (2016f), *OECD.Stat*, database, *http://dotstat.oecd.org/index.aspx?DatasetCode=ICT_BUS* (accessed September 2016).

StatLink http://dx.doi.org/10.1787/888933473741

Digitalisation promises greater control over production, greater flexibility in the scale and scope of production, and reduced operation costs (see Box 2.1 on the use of manufacturing execution systems [MESs]). In agriculture, for example, farmers generate data which companies such as John Deere and DuPont Pioneer can exploit through new data-driven software services (Noyes, 2014). For example, sensors in John Deere's latest equipment can help farmers manage their fleet of vehicles, reduce tractor downtime and save resource consumption (Big-Data Startups, 2013). The digital transformation of industrial production is also making certain industries more service-like, a trend sometimes described as "servicification" (Lodefalk, 2010). This approach has already been taken by firms such as Rolls-Royce, Boeing, Michelin and John Deere, to name a few (see sections below).

Today the IoT allows manufacturing companies to better monitor the use of their products and thus to provide customised pay-as-you-go services priced using real-time operational data. Rolls-Royce, for example, was a pioneer of this approach, when in the 1980s it stopped selling its jet engines alone, and began selling "power by the hour" – a fixed-cost service package over a fixed term (OECD, 2016b).[2] Data is now also used to monitor and analyse the efficiency of products and is increasingly commercialised as part of new services for existing and potential suppliers and customers. Germany-based Schmitz Cargobull, the world's largest truck body and trailer manufacturer, also uses the IoT to monitor the maintenance, travelling conditions and routes of all its trailers (Chick, Netessine and

The Next Production Revolution

Implications for Governments and Business

DOI:http://dx.doi.org/10.1787/9789264271036-en

This publication examines the opportunities and challenges, for business and government, associated with technologies bringing about the “next production revolution”. These include a variety of digital technologies (e.g. the Internet of Things and advanced robotics), industrial...