International Labour Organization

Robotics and reshoring

Employment implications for developing countries

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Preface

The ILO has taken a keen interest in how automation affects the quality and quantity of employment: decent work, in short. Much of the concern about new automation technologies and jobs is based on a narrow emphasis on substitution effects at the task level, but technology affects jobs no less importantly through complementarity effects, market expansion effects, income effects and input–output production linkage effects with associated income-induced effects. These effects can play out in different directions at different levels of aggregation, that is, at the task, enterprise, industry and economy-wide levels. Relatively absent in these discussions is a sense of how automation is playing out at the shopfloor level. This has motivated the ILO to undertake the industry case studies in this volume, focusing on the producers and potential users of new automation technologies and what their greater use might mean not just for employment but for the structure of global supply chains and the global division of labour. This volume addresses the implications of the increased use of robots and ITC-enabled automation, both manufacturing and services, in particular in the apparel, footwear and electronics industries as well as in retail warehousing in China and business process outsourcing (BPO) in India and Philippines.

Much of the discussion of the impact of automation on employment has focused on developed countries. Yet for developing countries a key concern is the prospect of "reshoring" or "nearshoring" – the opposite of offshoring – in which production, particularly of labour-intensive manufactures, shifts from developing back towards developed countries. These shifts in the global division of labour would be enabled by automation in such critical industries as those addressed by this volume, industries that have provided developing countries with strategic entry points into global markets and employ large numbers of workers who are (with the exception of warehousing) disproportionately women. The more readily and cheaply that work in these industries can be automated, the less readily can developing countries retain their competitive advantage based on lower labour costs. For lead firms in global supply chains, reshoring would provide the considerable advantages of lower transport costs as well as shorter lag times between design, production and final sales, enabling more just-in-time production. While there is not at present an overall trend towards reshoring, recent empirical studies find evidence that the increased use of robotics and other automation technologies in developed countries is associated with reshoring.

The case studies in this report were completed before the COVID-19 crisis hit. But even more than the crisis of 2008–09, the COVID-19 crisis has exposed the vulnerability of global supply chains, most immediately for multinationals reliant on China intermediate inputs and production, but now much more widely as the epicentre of the pandemic has shifted to Europe and the Americas. The current crisis has also lent urgency to the discussions on reshoring and nearshoring and the restructuring of global supply chains more generally. Professor David Autor, a leading voice of reason on the impact of automation on employment, has referred to the COVID-19 crisis as an "automation forcing event".[1] The questions addressed by this volume remain more urgent than ever, and it is our hope that it may offer a degree of concreteness to a debate that is often pitched at an abstract level.

Finally, we would like to express our sincere gratitude to the Government of the Republic of Korea for generously providing financial support for a research project on automation and employment, which comes to fruition with this volume.

Sangheon Lee
Director
Employment Policy Department
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1 Allison Dulin Salisbury, 2020. "COVID-19 May Become 'An Automation Forcing Event': Already Vulnerable Workers Look to Reskilling for Path Forward", in *Forbes*, 7 May 2020.

Contents

Preface iii
Acronyms and abbreviations ix

1. Introduction, by *Sukti Dasgupta* **1**
1.1. Job displacement due to technological feasibility: A literature review 3
1.2. Strategic industries, automation, and the global division of labour 10
1.3. The case studies and main findings 15
1.4. Conclusion 17

2. The apparel and footwear industry, by *David Kucera* **25**
2.1. Introduction 25
2.2. Automated sewing 28
2.3. 3D printing 35
2.4. Summing up: Jobs created, jobs lost, and the global division of labour 37

3. The electronics industry, by *Fernanda Bárcia de Mattos* **45**
3.1. Introduction 45
3.2. Automation in electronics manufacturing 48
3.3. Electronics manufacturing, automation and reshoring: Telling cases 53
3.4. Conclusion 55

4. Automation in Chinese retail warehouses, by *Xiao Jiang* and *Ansel F. Schiavone* **61**

4.1. Introduction 61
4.2. Understanding the technology 62
4.3. General trends of Chinese automation 65
4.4. Automation in Chinese retail warehouses 67
4.5. Nearshoring 73
4.6. Conclusion 75

5. Call centres in India and the Philippines, by *Xiao Jiang* and *Ansel F. Schiavone* **81**

5.1. Introduction 81
5.2. Understanding the technology 82
5.3. IVR development: Major players 84
5.4. Call centres: Major players 85
5.5. Indian and Filipino call centre industries 86
5.6. Total automation? 90
5.7. Reshoring 91
5.8. Conclusion 92

Tables

Table 2.1.	Exports and formal employees in top ten apparel exporters, 2000 and 2015 or latest year	26
Table 2.2.	Country unit sales of industrial robots in textiles, apparel and footwear, 1993–2016	31
Table 3.1.	Exports and formal employees in top ten electronics exporters, 2000 and 2015 or latest year	47
Table 3.2.	Global robot sales and stock in electronics (units) and share of total (per cent), 2000–2016	49

Figures

Figure 1.1	Trends in manufacturing value-added and GDP in industrialized countries and the rest of the world, 1990–2016	11
Figure 1.2.	Employment growth by sector, emerging and developing countries, 2005–17	12
Figure 1.3.	Global unit stock of industrial robots, 1993–2016	14
Figure 2.1.	Formal employees in the US apparel and footwear industry, 1963–2015	27
Figure 3.1.	Stock of robots by subsector and income group of the world and the top ten electronics exporters in 2015	50
Figure 4.1.	Amazon warehouse coordination between human workers (H) and Kiva robots (K)	63
Figure 4.2.	Robot density, by country	66

- **Figure 4.3.** Consumption of global industrial robot supply **67**
- **Figure 4.4.** Labour productivity in the Chinese auxiliary transportation sector **68**
- **Figure 4.5.** Labour inputs in the auxiliary transportation sector, by country **69**
- **Figure 4.6.** Gross output of the auxiliary transportation sector, by country **69**
- **Figure 4.7.** Skill composition of the Chinese auxiliary transportation sector **70**
- **Figure 4.8.** Labour productivity of auxiliary transportation sectors, by country **72**
- **Figure 4.9.** Chinese retail market growth **73**
- **Figure 4.10.** Chinese minimum wage, by province, 2016 **74**
- **Figure 5.1** Average call handling time, by country **87**
- **Figure 5.2** Labour cost as a percentage of total cost **88**
- **Figure 5.3** Range of annual call centre salaries vs. GNI per capita **89**

Acronyms and abbreviations

ASEAN	Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
BPO	business process outsourcing
EU	European Union
ICT	information and communication technology
IVR	interactive voice recognition/response
LED	light-emitting diode
LCD	liquid-crystal display
MoU	memorandum of understanding
R&D	research and development
RPA	robotic process automation
SIP	Sessions Initiated Protocol
SITC	Standard International Trade Classification
TCF	textile, clothing and footwear
TCLF	textile, clothing, leather and footwear
UNCTAD	United Nations Conference on Trade and Development
UNIDO	United Nations industrial Development Organization

1 Introduction

Sukti Dasgupta*

There is much concern today that new automation technologies and robotics will displace humans in the workplace. Yet, there is little knowledge about how automation will actually play out on the shopfloors and assembly lines of companies and enterprises in different sectors, or the bottlenecks at the practical level. These will affect the extent and speed with which new automation technologies are adopted, and have an impact on employment at the firm, sector and aggregate levels.

The widely quoted studies by Frey and Osborne (2013, 2017), and others using a similar methodology, have estimated that automation has the potential to replace up to 47 per cent of jobs in the United States, 55 per cent in Cambodia, 70 per cent in Nepal and 80 per cent in Ethiopia in the next decade or two (see World Bank 2016). Their research is motivated by the poor labour market outcomes in advanced countries, which they attribute largely to the substitution of labour by new automation technologies. Their methodology is based on the technological feasibility of potential automation of routine work; and as the share of routine work in labour-intensive manufacturing is higher in developing countries, the potential for job losses due to automation is systematically higher in these countries. As automation technologies substitute for relatively cheap manual routine work, the comparative cost advantage of developing countries in global supply chains could be eroded, and this could result in more and more reshoring of production and jobs to advanced countries (Tate and Bals 2017; Bals, Kirchoff and Foersti 2016). In other words, for most developing countries – except in some middle-income countries – the risk of job loss would not only be from automation in the country, but also, and more immediately, from automation in advanced countries.

However, technological feasibility is not the decisive factor nor the only factor in adopting new automation technologies and robotics (UNCTAD 2017a). The labour market impact of technological change and innovation is a complex process shaped by several factors, policies and institutions. Economic factors – relative prices, produc-

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tivity effects and market expansion effects, availability of skills, income effects – all play a role in the decision-making process. There is a difference between what could, in theory, be automated, and what will be automated. Furthermore, while it may appear that many routine jobs in labour-intensive industries can easily be done by robots, there may be bottlenecks to deploying new technologies. These technological and economic bottlenecks are often overlooked and unappreciated, but could create significant constraints for actual adoption of new technologies.

This book addresses the larger question of the impact of new automation and robotics technology on the geography of global production by probing two interrelated issues: How real is the case for technological feasibility and associated large-scale labour displacement from the perspective of the shopfloor; are there practical bottlenecks to adopting new technologies? Secondly, in the context of new automation and robotics technologies, will the comparative advantage of developing countries be eroded in favour of the reshoring of production to advanced countries? The answer to these questions will be industry specific, and therefore a sectoral perspective is necessary for a meaningful analysis.

Globalization and associated offshoring of production to developing countries was directed to certain sectors which played a vital role in the economic development of both developed and developing countries. We focus on those strategic sectors which have significant production and servicing facilities in developing countries, employ a large number of workers, often women, and have had a critical role to play in the development process through exports and global supply chains – namely the apparel and footwear industry, electronics assembly, warehousing in the retail industry, and business process outsourcing (BPOs) in services.

The case studies use primarily non-academic sources, including the business press, industry and engineering associations, and the producers, sellers and buyers of these new technologies. This method is complemented by available data on employment as well as innovation and diffusion (such as through technology sales information) in these sectors. Central to the study is the emphasis on how workers are likely to be most affected in both positive and negative senses, regarding both the quantity and quality of employment.

The findings of the industry studies are situated within the broader literature of the dynamics of technical change (such as via substitution, complementarity, and market expansion effects), and so are mindful of how the employment implications of new automation and robotics technologies, and the associated possibility of reshoring, differ according to the level of task and industry, and at aggregate levels as well as across sectors.

1.1. Job displacement due to technological feasibility: A literature review

There has been much speculation on what new automation technologies mean for "work" as we know it, as well as for the workplace. Robots are perceived as substitutes for human labour, or work. This is because robots have anthropomorphic characteristics – computers "think" and are intelligent. Robots have "arms" and "legs" and even "heads", and they can "walk" and "talk". On the other hand, they do not need to be paid wages and benefits, though there are maintenance and operation costs. There is, naturally, quite a bit of discomfort and fear that these new technologies are heralding a jobless or job-scarce era as functions that human beings currently perform are taken over by machines. This concern is reflected in public opinion surveys – such as that by the Pew Research Center which was carried out in ten countries and concluded that there is a widely shared view that the nature of work is likely to be transformed over the next half-century, with machines taking over much of human labour (Wike and Stokes 2018). The implications of such disruptive changes could be far-reaching for workers and industries. The report of the Global Commission on the Future of Work (ILO 2019) notes that "labour is not a commodity, nor is it a robot".

This concern, however, is not new. Back in the 1930s, Keynes had speculated whether technology would lead to unemployment even though it might result in higher living standards in the longer term. Indeed, technological change contributes to productivity growth by transforming a country's production structure to create better jobs and higher living standards. Previous technological revolutions, such as that which led to widespread use of the steam engine, for example, created major labour market disruptions. Many jobs were lost, but many new ones were created. For instance, the introduction of the power loom in the 19th century automated most of the work needed in weaving cloth, so that the nature of skills required for weaving changed. But the total number of weaving jobs increased even though the traditional handloom sector shrunk and created hardship for many traditional weavers (Bessen 2015). The question today is, will this phase of technological change, the so-called Fourth Industrial Revolution, be different from previous technological revolutions in its effect on net job creation? And what will be the implications of the ongoing technological revolution on the international distribution of production and work?

This book relates to two broad literatures: first, the vast and quickly expanding literature on the impacts of technology on the economy and labour markets; and second, the literature on offshoring and reshoring that examines the tradability of tasks and the extent and way to which workers in offshore locations compete with foreign robots in origin markets.

1.1.1. Routine versus non-routine tasks determine the extent of job displacement, though estimates vary

The literature on the impacts of technologies on labour markets includes empirical studies that look back at the historic impact of technology on employment, and forward-looking research which attempts to assess the potential outcome of the current wave of technological change. A common framework underlying this wide body of research sees jobs as comprised of a series of tasks which can be grouped under two categories: routine tasks that are rules-based and thus relatively easy to codify; and non-routine tasks that encompass manual tasks such as cutting hair, and cognitive tasks, including persuasion, which do not follow repetitive steps that can be translated into algorithms, and are thus harder to codify and automate (Autor 2014).

From a technical capabilities standpoint, Frey and Osborne (2013, 2017) argue that 47 per cent of US jobs are at high risk of automation through computer-controlled equipment. The researchers brought together a team of machine-learning experts to assess the work characteristics of over 700 occupations and determine potential job automation in the United States. Their methodology attributes very high risk to many occupations prevalent in developing countries in the industries analysed in the current case studies, such as for sewing machine operators and electrical and electronics equipment assemblers. The researchers admittedly focus exclusively on substitution effects and acknowledge that there are other forces at play which will ultimately determine the pace and extent to which jobs will actually be automated. Moreover, Frey and Osborne recognize that destruction effects have historically been accompanied by capitalization effects that lead to job creation. Their occupational-level probabilities of automation have, nevertheless, been applied widely. It has been estimated that about 55 per cent of jobs in five ASEAN countries (Chang and Huynh 2016) – namely Cambodia, Indonesia, Philippines, Thailand and Viet Nam – and Japan (David 2017) are susceptible to automation, while the share has been found to be higher than 80 per cent in Ethiopia, and over 70 per cent in Bangladesh, China, El Salvador, Guatemala and Nepal, among others (World Bank 2016). At a more aggregate level, the World Bank has suggested that two thirds of all jobs in developing countries could be at high risk of automation. In turn, estimates for higher-income countries such as the United States or those in Europe range from 35 to 60 per cent. As it is routine tasks that are most likely to be automated in the near future, workers in countries which rely on low-skilled labour face a higher risk of becoming redundant due to the adoption of new technologies.

Many other forward-looking studies utilize different methodologies in attempts to predict potential technological unemployment and arrive at rather different estimates. Despite also adopting a task-based approach, Arntz, Gregory and Zierahn (2017) estimate that 9 per cent of US jobs are at high risk of automation, substantially lower than Frey and Osborne's estimate. The former account for the heterogeneity of tasks within occupations, allowing task variability at the individual level, whereas the latter assume that the task makeup of an occupation is the same for all workers in that occupation. Arntz, Gregory and Zierahn (2016) propose that the potential for technologically feasible job displacement in OECD countries averages 9 per cent, ranging between 6 per cent in the Republic of Korea and 12 per cent in Austria. Building on this work, Nadelkoska and Quintini (2018) estimate impacts in 32 countries, suggesting that, on average, 14 per cent of jobs are associated with a high likelihood of automation, while another 32 per cent of jobs could experience marked changes in their task composition as a result of technology adoption. With a focus on work activities and performance capabilities, a study by the McKinsey Global Institute (2017a) estimates that only 5 per cent of occupations could be fully automated across 46 countries, though about 60 per cent of occupations could see at least 30 per cent of their activities automated. Subsequent research by McKinsey (2017b) attempts to go beyond technological feasibility and account for other factors such as costs, labour market dynamics and regulations, suggesting that between zero and 30 per cent of hours worked globally could be automated by 2030, depending on the scenario.

1.1.2. Research argues that automation raises productivity and total number of jobs, but lowers labour income share

Another strand of research looks to the past to understand the economic and employment impact of technologies; its findings suggest that fears of future technology-enabled unemployment may be exaggerated. Graetz and Michaels (2018) construct a replaceability index to estimate labour market impacts of robots, suggesting that between 1993 and 2007 robot usage led to greater labour productivity and value-added with no significant impact on total hours worked in 17 developed countries – although the share of hours worked by low-skilled workers declined in favour of medium- and high-skilled labour. Autor and Salomons (2018) empirically estimate employment impacts of automation, measured primarily by total factor productivity growth but also by robot adoption, in 18 OECD countries since 1970. Like Graetz and Michaels, they find that automation has not been employment-replacing even if it has reduced labour's share in value-added.[2] However, they do find that the displacement effect has become stronger with time and is highest in the 2000s, potentially because the latest technologies are labour-replacing rather than labour-augmenting. Conversely, focusing on commuting zones in the United States in 1990–2007, Acemoglu and Restrepo (2017) suggest that the adoption of industrial robots has been negatively correlated with employment. Their analysis indicates that more than five workers are displaced

2 Labour displacement is defined by Autor and Salomons as "productivity-enhancing technological advances that reduce labor's share of aggregate output" and thus relates to the wage bill rather than employment per se (2018, 2). In this framework, labour displacement requires that the wage bill rises less rapidly than value-added.

per additional industrial robot, most often routine manual workers in assembly and related occupations, and workers without college education. These impacts are, however, as Mishel and Bivens emphasize, small if compared to those of other drivers of change studied by Acemoglu and Restrepo, such as impacts from trade with China, equivalent to one third.[3] In addition, another indicator of automation, namely non-robot IT investment, was found to have a neutral or positive relationship with employment. Using the Acemoglu and Restrepo equilibrium approach, Chiacchio, Petropoulos and Pichler (2018) find that across six EU countries – which accounted for over 85 per cent of the EU's robots in 2007 – robots had significant displacement impacts between 1995 and 2007. An additional robot per thousand workers reduced employment by 0.16–0.2 percentage points. In turn, Dauth et al. (2017) had markedly different results in their application of Acemoglu and Restrepo's approach to Germany. They find that between 1994 and 2014, robots did not lead to overall job losses nor did they displace incumbent workers. Robot adoption did, however, lead to fewer new hires in manufacturing. Moreover, the Asian Development Bank (ADB) finds empirical evidence that between 2005 and 2015, robot adoption was associated with a decrease in routine employment and a rise in non-routine work – routine manual work, such as that of production workers, suffered the most (ADB 2018). Overall, they suggest, Asia should experience net job growth driven by rising demand and higher output, which will outweigh technology-enabled job displacement.

There is less evidence on the job creation aspect of new technologies, even if the studies on past and potential job destruction acknowledge that the displacement effect is accompanied by a job creation effect. Acemoglu and Restrepo (2018a) examine labour displacement and countervailing effects. They suggest that displacement effects could be effectively countered through the creation of new labour-intensive tasks that are also an outcome of technological progress. However, they caution that the labour market adjustment is complicated by skills mismatches and potentially by over-automation. In another study, Acemoglu and Restrepo (2018b) stress that automation reduces the cost of producing with labour, deterring further automation and stimulating the creation of new tasks in which labour has a comparative advantage. Addressing fears that technologies will render workers redundant, they highlight that a large share of US employment growth over the past 35 years is accounted for by new tasks and job titles. Gregory, Salomons and Zierahn (2019) find that between 1999 and 2010, routine-replacing technologies increased employment by 1.5 million in Europe. More specifically, they conclude that there has been job displacement, but that it has been more than compensated by job creation spurred by lower product prices and growing local income.

3 Moreover, Mishel and Bivens (2017) argue that the methodology used in this study provides quality local estimates of the impact of robots on the labour market, but presents only stylized facts at the national level. Indeed, Acemoglu and Restrepo, in their conclusion, underline that their methodology only directly estimates the effect of robots in a commuting zone relative to another, then attempting to model aggregate (national) effects.

The literature on the impact of technologies is vast and quickly expanding, and an exhaustive review is beyond the scope of this study. Some research (Prettner and Strulik 2017; Hémous and Olsen 2018) serves to highlight that there is no consensus on the impact of new technologies on jobs. In addition, predictions about a jobless future as a result of advances in and diffusion of technology require deeper probing. They often relate to stylized facts, or reflect research focused on technological feasibility and on what could potentially be automated, but automating is a complex decision based on economic considerations. Importantly, labour market impacts of technological change and innovation is a multifaceted and non-linear process encompassing job destruction and creation dynamics which will be shaped by existing and new policies and institutions (Nubler 2016). Whether and to what extent new technologies will be adopted and will hence translate into de facto automation (with job impacts) will vary by country, depending on the structures of the economy and labour market, as well as on demographics, regulations, tax regimes, consumer preferences and a range of other factors.[4] These are also drivers behind decisions on the location of production.

1.1.3. Drivers of offshoring and reshoring

Historically, firms have attempted to minimize the cost of production and maximize profits through reductions in the wage bill via offshoring to locations with abundant and low-cost labour (Strange and Magnani 2018). In production location decisions, these factors are weighed against transportation costs and delivery times, risk exposure, intellectual property rights and other legislation, managerial complexity, quality control and sustainability strategies, among other factors (Strange and Magnani 2018; Di Mauro et al. 2018). Changes in these considerations may lead to the decision to move offshored production back to the origin country, a phenomenon known as reshoring.

In a fashion not dissimilar to that of the research on potential impacts of automation, there have been attempts to quantity the tradability of tasks and the likelihood of certain occupations to be offshored.[5] In fact, the link between the routine nature

4 Given the profit-seeking nature of firms, wages also play a critical role in automation stories. Hémous and Olsen (2018) underline that higher wages raise incentives to automate, and thus automation increases as an economy develops.

5 Blinder and Krueger (2009), for instance, estimate that about 25 per cent of US jobs are offshorable based on job characteristics at the individual level. Van Welsum and Vickery (2005) estimated the offshorability of occupations by combining the intensity of ICT use with the ease of transmission of the final product or service via ICT, as well as limited need for face-to-face interactions, among other characteristics. They estimated that about 19 per cent of jobs in Australia, the EU 15 (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom) and the United States were in offshorable occupations in the early 2000s. Jensen and Kletzer (2010) found that about 27 per cent of US service occupations were in the highly tradable group, based on O*NET job characteristics.

of job tasks and their "computerability" outlined in Autor, Levy and Murnane (2003) has been articulated in Levy and Murnane (2005) in the context of the "offshorability" of such tasks – rules-based tasks which are easier to automate are also, they suggest, less costly to offshore. As in the task-based literature on automation, much of that on offshoring has found that "jobs with a high content of routine, non-interactive, and non-cognitive tasks [that] can be easily codified" have been easiest to offshore, as summarized by Vallizadeh, Muysken and Ziesemer (2016, 1). Whereas in manufacturing it is the routine and rules-based character of occupations which make them more prone to offshoring, in services the key trait of a tradable and offshorable occupation is whether the service can be delivered over long distances (thus not requiring personal interaction) with no loss in quality (Blinder 2007). Jobs such as factory jobs in manufacturing, and data entry or call centre occupations in services, rank amongst those easiest to offshore (Blinder 2007; Levy and Murnane 2005). In this context, the sectoral focus of the present study is aligned with sectors which have been found amongst those easier to offshore.

Recently, debates on reshoring have been gaining space. Chu, Cozzi and Furukawa (2013) outline an inverted U-shape pattern of offshoring and reshoring over the course of economic development. They suggest that a developing country with low capital stock and low wages attracts offshored labour-intensive activity. As the country develops, capital accumulation is accompanied by rising wages, rendering offshoring less attractive. This is, nevertheless, temporarily countervailed by a decline in the rental cost of capital. At some point in time, the increase in wages outweighs the decline in the rate of capital rental, leading to reshoring. Recent research by Krenz, Prettner and Strulik (2018) introduces to this framework an alternative way firms can save on the wage bill: productivity-enhancing automation technologies in origin countries. Using panel data for developed countries in 2000–14, they find that automation measured as an increase in the robot–worker ratio is positively associated with reshoring. Faber (2018) also proposes that the use of robots may reduce the relative cost of domestic production, decreasing the comparative advantage of low-cost labour in offshore locations, thus facilitating reshoring. Using data for Mexico between 1990 and 2015, Faber builds on Acemoglu and Restrepo (2017) and constructs a measure of local market exposure to domestic and foreign robots. He finds that the use of robots in the United States is negatively related to employment in Mexico by reducing exports to the US. Moreover, Faber finds that effects are particularly negative for low-skilled machine operators and technicians in manufacturing, and high-skilled service workers in managerial and professional occupations. Dachs, Kinkel and Jager (2017) analyse data for over 2,000 Austrian, German and Swiss firms and conclude that the adoption of new digital technologies is associated with greater propensity to reshore. However, they stress that reshoring remains a rare phenomenon. This is corroborated by the 2018 Kearney Reshoring Index, which indicates that while reshoring has seen an increase over the last five-year period, it is not significant. Until 2018, offshoring continued to be more prevalent than reshoring, and although in 2019 the Kearney Reshoring Index experienced a sharp reversal, this is attributed to a decline in imports from China, due to US-China trade tensions, rather than to a rise in US manufacturing output.[6]

Many have sought to understand the drivers of offshoring and reshoring – a recent review of literature by Di Mauro et al. (2018) highlights the complexity of production location decisions, having identified 24 distinct motivations for offshoring and 42 for reshoring. Other research (Cohen et al. 2016) suggests that for leading manufacturing companies in Europe, Japan and the United States, location decisions are no longer driven primarily by costs (labour and otherwise), but are the result of a combination of factors ranging from quality, agility, market access and risks.[7] In future, reshoring of activities, or near-shoring, may therefore become increasingly attractive.[8] However, if some reshoring were to take place, these shifts could be balanced by new manufacturers in low-cost locations and growing consumer markets in emerging countries, coupled with the trend towards production close to consumer markets (De Backer and Flaig 2017). Research by UNCTAD (2017a, 2017b) suggests that there is continuing scope for developing countries to engage in traditional industrialization processes, especially if they embrace technological change.

In sum, in spite of a multitude of approaches and a wide range of results, it is largely agreed that routine tasks are the most susceptible to automation and there is a likelihood of such tasks being automated over time, though the pace and depth of automation will depend on several factors. It follows that workers in countries which rely on low-skilled labour face higher risks of becoming redundant due to the adoption of new technologies. As Faber (2018) highlights, low-skilled workers in developing countries which rely on offshored activities are in competition with automation in high-income countries, which increasingly have in automation technologies an alternative to low wages in their profit-seeking efforts to lower wage bills. However, as underlined by Autor and Salomons (2018), "comprehensive evidence on the labour-displacing channel is at present limited" (3). In addition, we argue, tasks that may seem in theory easy to automate may in reality face a number of bottlenecks preventing or delaying automation. The current study contributes to the literature on automation, employment and reshoring by offering a nuanced

6 https://www.atkearney.com/operations-performance-transformation/us-reshoring-index, accessed on 3 February 2019; see also A.T. Kearney 2020. The 2019 Kearney Reshoring Index report indicates that there was an increase in imports from other low-cost Asian countries as well as from Mexico.

7 This relates to corrective decisions related to the difficulties, in offshore locations, of protecting intellectual property and ensuring quality levels, for instance. At the same time, the authors suggest, firms increasingly value agility, market access and lower risks.

8 Scenarios include trade policy, growing demand in emerging economies, digitalization of production, new (low-cost) producers in manufacturing, rising wage costs, and rising transport costs (De Backer and Flaig 2017).

perspective on the interplay between technology and employment, focusing on a few sectors and identifying differences between what theory suggests to be automatable and bottlenecks encountered in practice. It argues that the existing technical and economic bottlenecks are often overlooked. The case studies seek to assess the depth and scope of automation in key sectors and the effects on worker displacement and costs, as well as on the global division of production and labour at an aggregate level. The studies therefore provide a good starting point for discussion from a sectoral perspective.

1.2. Strategic industries, automation, and the global division of labour

Labour-intensive manufacturing industries such as textiles, footwear and electronics have been critical in the growth and development of developed and developing economies. Their expansion resulted in a productivity shift in these economies while absorbing large numbers of relatively unskilled workers, underpinned by trade and globalization, and the development of global value chains. Manufacturing`s share of total global trade rose substantially in the 1980s and 1990s, much of the production taking place in developing countries. While the offshoring of manufacturing is older, that of services is more recent, spurred by improvements in information and communications technologies (ICT), lower trade barriers, and rapid socio-economic development accompanied by the accumulation of human capital and infrastructure in middle-income countries (Blinder 2007; Vallizadeh, Muysken and Ziesemer 2016; Strange and Magnani 2018).

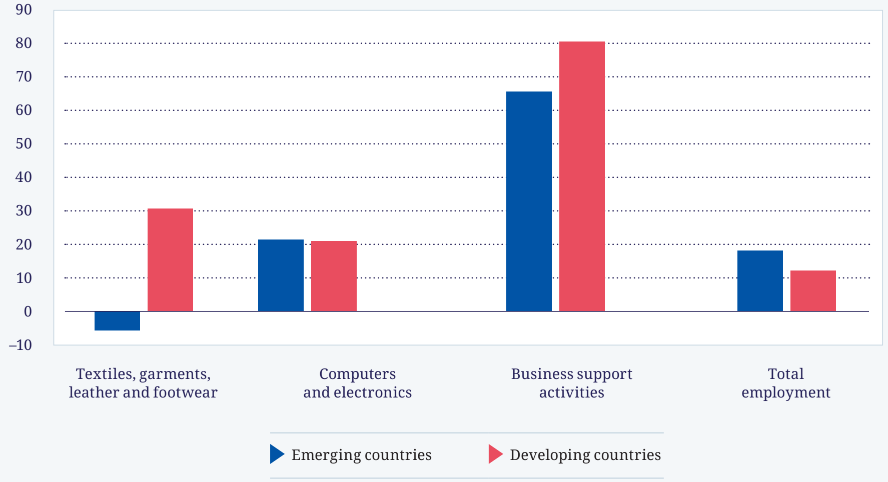
Offshoring of production and services to lower-cost locations has been a marked feature of the contemporary global economic landscape and has contributed to structural transformation and socio-economic development processes across low- and middle-income economies. At the global level, this led to a shift in production from north to south, as multinational companies shifted their production to lower-cost locations (figure 1.1). The decline in share of workers in manufacturing in advanced countries began in the 1970s while it grew in developing countries, mainly Asia (UNCTAD 2016a; UNIDO 2017). This era of industrialization and globalization was also accompanied by reductions in poverty in developing countries in Asia, notably China, though inequality levels rose in many countries.

The transformation in developing countries during this phase of industrialization was in part driven by new ICT technologies that transformed production processes, communications and transportation. These economies exploited the opportunities made possible by the ICT revolution and built sustainable competitive advantage in many industries and services (Hanna, Boyson and Gunaratne 1996; Ranis 1995). Furthermore, in some countries such as India and the Philippines, the growth of

▶ Figure 1.1. Trends in manufacturing value-added and GDP in industrialized countries and the rest of the world, 1990–2016

▶ Source: Authors' calculations based on UNIDO Manufacturing Value Added Database. Adapted from figures 7.5 and 7.6 in UNIDO 2017.

Figure 1.2. Employment growth by sector, emerging and developing countries, 2005–17 (per cent)



Source: ILO Labour Force Micro-dataset v1.5, and author’s calculations.

ICT technologies and a huge pool of English-speaking young workers created the conditions for offshoring of the business processes of major companies in advanced countries to cheaper locations in these developing countries. Call centres flourished as a result, creating jobs for many young women and men.

The other sector which has witnessed high rates of employment in both developed and developing countries is the trade and retail sector. In developing countries, higher incomes amongst the middle class led to higher purchasing power, along with the proliferation of mass marketing strategies and online shopping. While this has often had a negative impact on jobs in the traditional retail sector (Saha 2016; Wang and Qu 2017), several ancillary jobs were created in the storage and warehousing industry which supports that sector.[9]

These strategic industries have helped create jobs in the modern formal sector, though these are relatively low-skilled, low-wage jobs (figure 1.2). The textile, clothing, leather and footwear sector (TCLF) is highly competitive, and over the last many

9 See Chapter 5.

years has contributed to many present-day emerging countries[10] increasing their share of industrial employment. Between 2005 and 2017 in developing countries, the sector registered a positive 30.7 per cent growth rate in employment. However, for many emerging countries, while employment in the sector was growing fast in initial years it has seen a decline more recently, dominated largely by trends in China. In emerging countries, therefore, the sector over the period 2005 to 2017 shows a negative employment growth rate of –5.4 per cent. The electronics sector on the other hand has been increasing its employment in both emerging and developing countries at 21.3 and 20.9 per cent respectively. The business support activities, which include among others BPO services, have a very strong growth rate in both emerging and developing countries, at 80.6 per cent in emerging countries and 80.6 among developing countries.

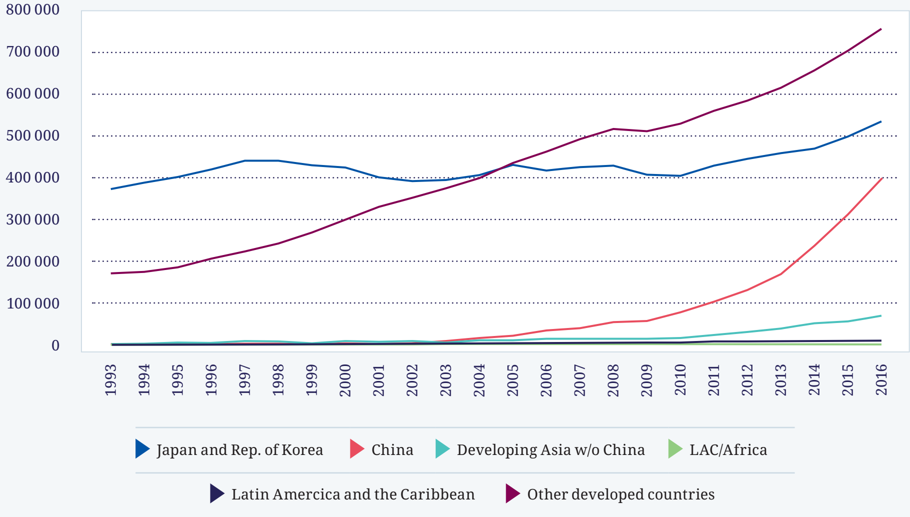
These industries have a high share of routine jobs, which in theory can be automated, and are therefore seen as having the risk of being reshored to advanced countries, with implications for jobs in developing countries. The question is how fast and how deep will be the pace of automation in these industries and how the overall effect on employment will play out.

The stock of robots (IFR 2018) provides a relatively good indication of current trends in automation in industries, especially in assembly lines. As figure 1.3 shows, the global stock of robots has been rising since the early 1990s, at a faster pace since the onset of the century, and particularly after 2010. The Asia and the Pacific region, home to the largest population and labour force, interestingly leads in terms of stock of robots. This mirrors the high stocks of robots in Japan and the Republic of Korea, and the fast-rising stock of robots in China.

Data from the International Federation of Robotics (IFR 2018) also shows that the manufacturing sector has the highest stock of robots, and the automotive industry leads with the largest share of the global stock of robots (37.3 per cent in 2016), followed by electronics (13.3 per cent). Textiles and garments account for just 0.1 per cent of the total stock of robots. The number of operational robots in the TCLF sector declined between 2003 and 2009. It has risen sharply since then, driven by Asia and the Pacific, and to a much lesser extent, the Americas. In turn, the stock has not risen in Europe beyond early 1990s levels. In the electronics industry, there has been a sharp rise in the stock of operational robots since 2009. This was driven by Asia and the Pacific, which accounted for 85 per cent of the global stock in 2016. The second largest stock is in the Americas, equivalent to 11 per cent of the total.

10 Emerging countries include Brazil, Colombia, Ecuador, Guatemala, Jordan, Mexico, Peru, South Africa, Thailand and Turkey. Developing countries include Angola, Bangladesh, Cameroon, Democratic Republic of Congo, Egypt, Ghana, India, Indonesia, Côte d'Ivoire, United Republic of Tanzania, Viet Nam and Zambia. The period is 2005–2017; years vary slightly depending on the countries. Source: ILO Labour Force Micro-dataset v1.5, and author's calculations.

Figure 1.3. Global unit stock of industrial robots, 1993–2016



Source: IFR 2017.

The more advanced economies that have the infrastructure for automation and are pressed with labour shortages due to ageing are likely to be the first to see the impacts of automation. Indeed, it has been shown that a positive association exists between ageing and the development and use of robot technology (Abeliansky and Prettner 2017; Acemoglu and Restrepo 2018c). However, if we factor in the possibility of reshoring because of the labour displacement effect of new automation technologies, the impact will be much more complex, as some industries return (albeit with a different set of requirements for workers) to advanced countries, eroding the low-cost labour advantage of developing and emerging countries (UNCTAD 2016b; Hallward-Driemeier and Nayyar 2018). The use of robots in traditionally labour-intensive industries such as apparel, electronics, BPOs and retail can therefore have far-reaching effects, and change the geography of production – as production moves back to advanced countries, or closer to home, in proximity to designers and customers.

In fact, offshoring has continued to dominate reshoring. The reasons for this are the cost advantages in overseas low-cost locations and shortage of skilled labour for relevant industries in advanced countries.[11]

11 https://www.atkearney.com/operations-performance-transformation/us-reshoring-index, accessed on 3 February 2019.

1.3. The case studies and main findings

The possible employment implications of the increased use of robots and ITC-enabled automation in manufacturing and service sectors are examined through case studies on apparel, footwear and electronic assembly in manufacturing, retail warehousing in China, and the BPO sector in India and Philippines.

The apparel and footwear industry has long been strategic in economic development as an entry point into global markets and as a creator of jobs. Its growth in developing and emerging countries has been facilitated by globalization, the development of global value chains and low labour costs. Recently, rising labour costs in developing countries coupled with a number of concerns over improving the fashion industry value chain – such as transport costs, delivery times and environmental footprints – have raised fears over potential reshoring. A global rearrangement of production would, however, depend on the potential of new technologies (including automated sewing and 3D printing) and the availability of skilled workers in high-income countries, among other things. Moreover, innovations suggest potential for job displacement but also for worker–robot collaboration. At this point in time, the likely impacts of new automation technologies on the number and location of jobs in the apparel and footwear industry remain unclear.

The electronics industry is one of the largest goods-producing sectors, accounting for large shares of global trade and employing an estimated 18 million people. Since the 1980s, production has moved towards lower cost locations, particularly Asia where it has been an engine for social and economic development. As emerging technologies that reduce the need for human labour become more affordable and labour costs in traditional low-cost labour locations rise, the consumer electronics manufacturing landscape could change. In spite of fears over a rearrangement of production towards high-income countries, prospects are uncertain. Although robot deployment in assembly of electronics is increasing across the world, it remains limited and assembly employment is likely to remain significant at least in the near future. At the same time, anecdotal evidence suggests that firms are making investments in expanding capacity in high-income and low-income countries alike, indicating that fears about reshoring and job loss may, at this stage, be overstated.

Over the past few decades, explosive growth in purchasing power has led to the development of a thriving Chinese retail industry. More recently, the expansion of online shopping has led to the rapid development of the warehouse industry. Early examples have shown robotic automation to be extremely effective at cutting labour costs and reducing warehouse employment, while increasing storage capacity. If Chinese retailers were to follow in the automation footsteps of the likes of Amazon, this could drastically reduce the number of warehouse jobs currently available to Chinese workers. Higher wages in large urban centres could also lead to the relocation of warehouses towards peri-urban areas, with impacts on employment. However, investments in technology are not without risk and Chinese retailers are likely to adopt automation gradually. With demand expected to rise as the middle class continues to expand, there could be both greater automation and employment, with worker displacement a possibility for the distant future.

Call centres make up a large portion of the BPO industry, handling customer services for companies from around the world. About seven in ten call centre workers are in India or the Philippines, largely due to the combination of proficiency in English and low labour costs. Vocal recognition technology and chatbots increasingly allow companies to, at least partly, substitute workers, reducing the need for labour and thus potentially facilitating reshoring. On the other hand, emerging technologies may lead to a shift in the tasks of call centre workers, beyond basic customer service towards higher skilled specialized work and thus changing workers' profiles rather than displacing labour. Overall, technological bottlenecks, relative costs, customer preferences and other factors will codetermine the extent to which automation is adopted as well as where this type of service is located.

The four case studies in this book serve to highlight the specificities of each sector. The electronics sector, which has one of the highest rates of robot deployment, still needs humans in much key routine work. Electronics assembly operations that require picking up the correct part among an assortment of parts, and inserting small flexible parts into tightly-packed consumer electronics, continue to be done by humans. Furthermore, investment in expanding capacity and continued growth of demand could counter job losses from automation in the industry. In the apparel sector, which has a much lower robot usage compared to electronics, humans are working alongside semi-automated machines. 3D printing in the clothing sector can break down the difference between textile production and apparel production, but at the current time 3D printing of soft garments for the mass market is not imminent though it has made more inroads in the footwear industry. These initiatives may not result in fewer jobs in the company's supply chain, given that the market for footwear is rapidly expanding and the footwear market would cater to high-end niche markets as well as mass markets. In the retail warehousing industry in China, which requires lifting and moving goods, hydraulic arms and wheeled robots are in use. However, there are challenges in coordinating different fleets of robots, and tasks such as inventory management are still the domain of humans. Market expansion in this sector has continued to demand human labour. In the call centres, the use of interactive voice recognition (IVR)[12] and text-based attendant automation (chatbots) could displace humans, and could see some reshoring of call centres back to advanced countries, but market research shows that consumers prefer speaking to humans rather than to machines, which could limit the extent of automation in this sector. Overall, the case

12 IVR is not robotics as defined by the International Federation of Robotics, but the artificial intelligence algorithms used in the next generation of IVR are similar to advanced robotics.

for large-scale labour displacement due to new automation and robotics technologies appears to be unsupported by the case studies.

1.4. Conclusion

The fear of jobless growth due to new automation technologies and robotics is aggravated by the current global employment scenario which has been rather unstable since the economic crisis more than a decade ago and has suffered a major new blow during the coronavirus pandemic. The Covid-19 health crisis which snowballed into a major economic and labour market crisis is likely to reduce working hours by around 10.7 per cent in the second quarter of 2020 relative to the last quarter of 2019, which is equivalent to 305 million full-time jobs (ILO 2020).

The textile and electronics industries studied here are likely to be amongst those most affected by this crisis as lockdown measures to contain the spread of the virus dramatically slash production and jobs. As countries scramble to stimulate economies, support industries and recover jobs and incomes, how technology adoption will play out will depend on profit and productivity decisions but also on political decisions to ensure jobs and demand. In light of these uncertainties that engulf the global economy currently, it is necessary to take a practical and dispassionate view about the opportunities and challenges of new automation technologies and robotics.

A major part of the discussion on the effect of these new technologies on employment has revolved around the potential for automation in routine tasks. It is certainly true that new robotic technologies are increasingly able to automate work traditionally done by hand in labour-intensive industries which have historically provided strategic entry points into global markets for developing countries, as well as employment opportunities for women and young workers. As the capability of new technologies expand and their cost falls, there are concerns that production may significantly shift from developing to developed countries, leading to a change in the global division of labour. With developing countries looking to tradable services as entry points into global markets, similar concerns apply to such services, for which robots and ITC-enabled automation are making significant inroads. The case studies in this book use company-level information and anecdotal evidence, as well as data on robot use, to objectively present the scenario in four sectors that are critical entry points for developing countries in the global production chain. The case studies assess some common beliefs about the ability and pace of automation in four key sectors – clothing and apparel, electronics, retail warehousing and BPO-related services in call centres, and examine new automation and robotic technologies from a shopfloor and assembly line perspective, rather than how routine or non-routine the tasks are. The research finds that there are several bottlenecks to adopting new technologies at shopfloor level. There are still substantial limitations to the use of robots in activities which, although repetitive and thus seemingly easy to automate in theory, require (among others) flexibility and dexterity that machines are yet not fully able to replicate – such as perfectly aligning two pieces of pliable fabrics for sewing.

Much concern about new automation technologies and jobs is based on a narrow emphasis on labour displacement effects at the task level. However, as the case studies highlight, technology affects jobs also through *complementarity* effects, where robots work in collaboration with humans, and *market expansion* effects. They underline the importance of better understanding the extent to which new technologies and robots will displace humans on the shopfloor and assembly lines, and how the content of existing jobs could change. Moving away from net job creation and destruction estimates, it is essential to assess how production processes and jobs in strategic sectors would be affected, including at the task level, and the implications for job quality.

Historically, the net positive employment generation effects of technology have dominated. Nevertheless, there are concerns that the new automation technologies could be different in terms of their pervasive effects on how production is organized and the nature and conditions of work. The case studies indicate that automation may not present an immediate threat to jobs on a large scale in developing and emerging countries, yet it would be ill-advised to be dismissive of concerns over reshoring and near-shoring. The costs and capabilities of new automation technologies are rapidly evolving, productivity is rising, and associated labour costs in many developing countries are also likely to be adjusted upwards. Global sales of industrial robots increased by 31 per cent between 2016 and 2017 (IFR 2018). Moreover, tariffs and global politics could potentially encourage reshoring. Being aware of the potential of such transformations is necessary, even though their nature and speed will vary considerably across sectors, countries and categories of workers.

Overall, on the basis of the analysis in the four case studies, it is fair to say that large-scale replacement of humans by machines in the sectors studied is unlikely in the near future, as is the possibility of large-scale reshoring. Near-shoring and moving to other locations within developing countries due to various competitive reasons, as highlighted in the case studies on electronics and call centres, are possibilities, though not necessarily linked to new automation technologies. Furthermore, the actual impact on employment would depend on the ability to overcome the technological bottlenecks that exist, and the extent to which products are for niche markets or mass markets, as well as economic factors such as relative costs. Nevertheless, much of what actually happens and how fast these changes take place will depend on policies and social dialogue at the sectoral, national and global levels.

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2 The apparel and footwear industry

David Kucera*

2.1. Introduction

The apparel and footwear industry has long been strategic in economic development as an entry point into global markets and, being highly labour-intensive, as a creator of jobs. In both developed and developing countries, workers in the industry are also disproportionately female (Kucera and Tejani 2014). The industry has experienced extensive offshoring from developed to developing countries in recent decades and is also one of the most important industries as regards integration into global supply chains, along with the automobile and electronics industries (Sturgeon and Memdovic 2011).

Table 2.1 gives a sense of the extent of offshoring in the last 15 years from developed to developing countries, particularly in Asia. The table shows exports for and numbers of formal employees in the industry for the world's top ten apparel exporters, accounting for 87 per cent of global apparel exports as of 2015.[13] For the eight developing exporters shown in the upper panel of the table, apparel exports totalled US$287 billion in 2015 and employment increased from 6.5 million in 2000 to 15.5 million around 2015. China is by far the most important among these eight in terms of exports and employment, accounting for 61 per cent of their exports as of 2015 (67 per cent if one includes Hong Kong) and with its share of employment holding steady at about 50 per cent over these years. For 2015, apparel exports for the European Union (EU) 28 totalled US$112 billion– second only to China – compared to US$6 billion for the United States. The much larger volume of exports from the EU 28 than the US is striking, suggesting that EU producers have been much better at holding their own in global markets than their counterparts in the United States.[14] Yet employment has

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13 As the UNIDO User's guide (2011, 33) notes, these data exclude "home workers … working proprietors, active business partners and unpaid family members".

14 It may be the case, however, that this reflects a higher share of imported intermediates embodied in EU 28 than US apparel exports.

Table 2.1. Exports and formal employees in top ten apparel exporters, 2000 and 2015 or latest year

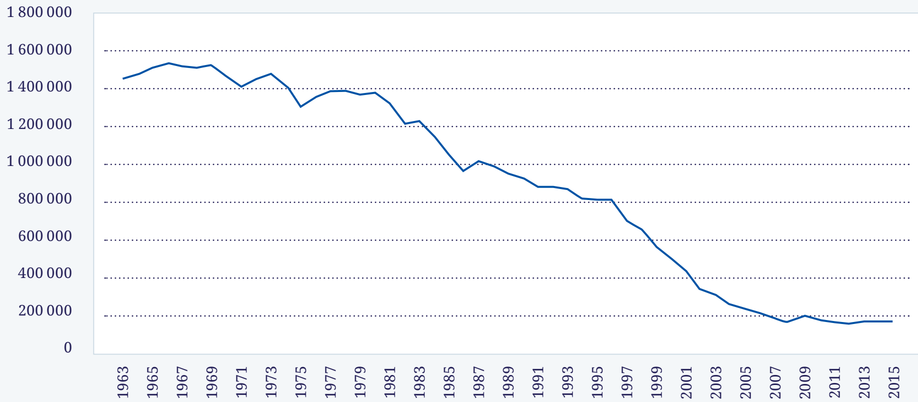
	Exports 2015 (US$ billions)	Formal employees	
		2000[1]	2015 or latest year[2]
China	175	3 284 000	7 661 200
Bangladesh	26	1 037 310	2 827 468
Viet Nam	22	511 364	2 314 288
Hong Kong, China		28 200	11 650
India	18	469,195	1 342 454
Turkey	15	164 212	563 593
Indonesia	7	761 183	n.a.
Total, developing countries	287	6 459 076	15 508 435
EU 28	112	2 279 365	1 314 928
United States	6	498 472	167 223
Total, developed countries	118	2 777 837	1 482 151

- Notes: [1] Bangladesh, 1998. [2] China, 2014; Bangladesh, 2011; Viet Nam, 2014; Hong Kong, China, 2015; India, 2015; Turkey, 2015; Indonesia, 2015; EU 28, 2015 (except Ireland, 2012; Malta, 2011, Slovenia, 2014); United States, 2015. n.a.= not available.
- Sources: WTO 2016 (refers to SITC 84: Articles of apparel and clothing accessories, and does not include footwear); UNIDO 2017 (refers to ISIC (rev. 4) 14 and 15: Wearing apparel, fur, leather, leather products and footwear).

dropped sharply in both the EU 28 and the United States since 2000, by 42 per cent in the former and 66 per cent in the latter. While in 2000 the EU 28 and United States accounted for 30 per cent of employment in the industry among these ten exporters, this plummeted to just 9 per cent around 2015, a massive compositional shift in employment in such a short span of time.

In spite of these trends, there is considerable interest in the prospects for reshoring as well as nearshoring in the apparel and footwear industry. A study by consulting firm A.T. Kearney (2014) documented over 700 cases of reshoring to the United States

Figure 2.1. Formal employees in the US apparel and footwear industry, 1963–2015



Source: UNIDO, 2017

in recent years, 12 per cent of these for the apparel industry.[15] Similarly, the US-based Reshoring Initiative documented 75 cases of reshoring to the United States for the textile and apparel industries from 2007 to 2015, resulting in the creation of 3,226 jobs (Anson 2016). Yet this does not mean that there was more reshoring than offshoring in the industry – that is, that there was net reshoring, in terms of either production or employment. It is instructive in this regard to consider more long-run employment trends in the US industry, shown in figure 2.1. From around 1.5 million employees in the 1960s, employment has dropped sharply, to well under 200,000 employees in recent years (as also shown in table 2.1 for 2015). This decline resulted in a shortage of skilled operatives as well as technicians to maintain sewing machines, which is argued by industry insiders to be one of the key impediments to reshoring to the United States (Anson 2016).

Yet a number of reasons have been advanced in favour of reshoring, particularly in light of rising labour costs in many developing countries. These include the potential for reduced transport costs and delivery times, less surplus inventory sold at discounts as production becomes more just-in-time, closer proximity to designers, improved

15 The apparel industry ranked third among industries in this regard. Other industries in the top four were electrical equipment, appliances and components, at 16 per cent; transportation equipment, at 14 per cent; and computers and electronics at 11 per cent.

product quality, reduced corporate social responsibility risk and improved brand image (Anson 2016). The last of these is particularly important for luxury brands for which part of their cachet is their association with a particular country, such as Burberry in the United Kingdom and Brooks Brothers in the United States, both of which have reshored apparel production in recent years for this reason (Davidson 2013; Robinson and Hsieh 2016). Might such examples of reshoring be spearheading a trend that could significantly affect the overall global division of labour in the industry? One study based on interviews of members of US Fashion Industry Association in 2014 suggests not, concluding that "it is not realistic to expect a substantial return of apparel manufacturing in the United States at least in the near future" (Lu 2015, 2). This contrasts sharply with the findings of a survey of apparel sourcing executives and managers as well as industry participants undertaken in 2018, featured in the McKinsey report *Is apparel manufacturing coming home?* The survey found that "79 percent of respondents in our survey believe that a step change in nearshoring for speed is highly/somewhat likely by 2025" (Andersson et al. 2018, 8).[16] In terms of the nearshoring of production for sales to the North American market, much of this was expected to be in Central America, but survey respondents replied that they expected fully 30 per cent of such production to be in the United States. The report argues that the economic viability of such nearshoring and reshoring depends critically on the use of new automation technologies in apparel production.

How the dynamic between automation and reshoring plays out depends, though, on the potential of new automation technologies in the industry and the extent to which these could address concerns about the shortage of skilled operatives (in the United States if not the EU countries) as well as overcome developing countries' competitive advantage based on lower labour costs. There are a number of potentially relevant technological developments in the industry in this regard, including automated fabric cutting and apparel knitting and seamless garments. We focus on two developments that have received the most attention in the industry: automated sewing and 3D printing as well as related developments in footwear.

2.2. Automated sewing

A study by the ILO concludes that "Significant shares of TCF [textile, clothing and footwear] workers in ASEAN are at high risk of automation, from 64 per cent in Indonesia, 86 per cent in Viet Nam and 88 per cent in Cambodia" (Chang, Rynhart and Huynh 2016, x). These findings are based on a method developed by Frey and Osborne (2013) in their widely-cited study. Frey and Osborne's method applies their

16 The report also provides this extraordinary survey finding: "82 percent of respondents believe that simple garments will be fully automated, affecting an 80 percent labor reduction by 2025. 70 percent think that it is highly/somewhat likely that more complex garments, such as dresses and jackets, will be significantly automated (resulting in a 40-percent labor reduction)" (21).

estimates of the risk of potential automation by computer-controlled equipment in the next 10 or 20 years for different occupations. These estimates are based on a database describing work characteristics of occupations combined with assessments made by machine-learning researchers of 70 occupations which are then imputed to 632 other occupations (based on similarity of work characteristics) for a total of 702 occupations. Particularly relevant in this regard are the following occupations and associated estimates of the risk of potential automation: for sewing machine operators, 89 per cent; for hand sewers, 99 per cent; for shoe and leather workers, 52 per cent; and for shoe machine operators and tenders, 97 per cent.

It is worth emphasizing that these are estimates that an occupation could be automated, which is a purely technological consideration. Estimating the probability that an occupation would be automated is, however, both a technological and economic consideration. That is, investments in new automation technologies would only be made in so far as they are thought to be at least as profitable as prevailing production methods. This depends on the relative costs of new automation technologies (not just purchase costs, but also the costs of getting and keeping them up and running) as well as of the relative costs of labour with prevailing methods versus the possibly more skilled labour required by new automation technologies.

It is also important to bear in mind that the industry is largely structured into global supply chains, and that the ability and incentive for establishments to invest in new automation technologies depends on where they are situated along the chain. In particular, supplier firms down the chain may lack the resources as well as the incentive to undertake such investments unless this improves their bargaining position with respect to lead firms such that they are able to adequately capture the gains of associated productivity increases. Lead firms might be better positioned to undertake these investments, which in this sense could be associated not just with a reversal of offshoring but also a reversal of outsourcing, depending on whether lead firms directly own and operate the new production facilities. This could in turn depend on whether the lead firms are brands or retailers, and the role of intermediary agents and large contract manufacturers in supply chains also merits consideration. Affecting the incentive to invest in the industry more generally is current productive overcapacity, manifested in the concerns of many brands and retailers about their extensive use of deep price markdowns (Donaldson 2017).

While the automobile and electronics industries have been leaders in terms of adopting new automation technologies, particularly robotics, the apparel and footwear industry has been a laggard. This is suggested by a summary of a roundtable discussion of over 25 apparel sourcing executives hosted in 2016 by the consulting firm McKinsey and Company:

> Advances in virtual design, digital printing, robotics, and automation are transforming the way companies in many industries design and make their products. Yet, with so much groundwork still to be done in optimising apparel-sourcing processes, the majority of

> participants felt that the apparel industry is at a very early stage in terms of adopting these approaches. (McKinsey 2016, 44)

The impression of the apparel sourcing executives is confirmed by data from the International Federation of Robotics database. Shown in table 2.2 are the number of robots sold in the textiles, apparel and footwear industries in the ten countries with sales of ten or more robots in any given year between 1993 and 2016. As the database does not provide more detailed breakdowns, textiles are grouped together with apparel and footwear and so the table overstates the use of robots in apparel and footwear, the subject of this study. This is all the more so in that the production of textiles generally lends itself more readily to automation than the production of apparel and footwear, and so a disproportionate share of robots is likely to be in textiles. One must also bear in mind that some of these robots are used in ancillary operations such as packaging rather than in direct production.

These qualifications noted, comparing with table 2.1, China is the only developing country among the top ten apparel exporters that also features in table 2.2, and indeed the only developing country in table 2.2, aside from Taiwan, China. Sales of robots in China were negligible before 2014, but over 100 robots were sold in these industries each year from 2014 to 2016, a considerably greater number than any other country. In contrast, in both 2015 and 2016, no robots were sold in Denmark, France, Republic of Korea, Spain and Taiwan (China). Italy has seen fairly stable annual sales of robots going back to 1994, whereas annual sales have been more variable though still significant in Germany. Finally, the United States has seen steady sales increases from 2011 to 2016, though this peaked at just 39 robots in 2016. In sum, while there is significant variation among countries in the sales of robots in the textiles, apparel and footwear industries, these are dwarfed by sales in the automotive and electronics industries.

Why are there so few robots in the apparel and footwear industry? Though the cutting of fabrics has been automated to a considerable extent, sewing continues to be predominately done by the familiar process of workers manipulating pieces of fabric by hand through stand-alone sewing machines. Wages tend to be low in the industry, creating less incentive to automate, but a fundamental impediment is technical. This results from the pliability of fabrics, pieces of which need to be accurately aligned before they are sewn, something the human hand and eye can readily accommodate but which poses daunting challenges for automation. This challenge is exacerbated by the vast range of apparel products, the rapid changes in product demand (witness fast fashion), the varied properties of different fabrics, and the range of sizes in which any given product must be produced. The implication is that Frey and Osborne's estimates for relevant occupations may be too high, with the qualification that technical developments two decades hence are difficult to anticipate.

To address this issue, we next consider how three companies endeavouring to sew with robots are dealing in very different ways with common technological challenges.

▶ Table 2.2. Country unit sales of industrial robots in textiles, apparel and footwear, 1993–2016

	United States	China	Japan	Rep. of Korea	Taiwan, China	Germany	Spain	France	Italy	Denmark
1993	0	0	0	0	1	60	12	5	3	0
1994	0	0	0	0	1	139	0	9	29	0
1995	0	0	0	0	13	0	0	7	22	0
1996	0	0	1	0	1	0	0	13	50	1
1997	0	0	12	0	50	18	4	18	50	7
1998	0	0	7	0	0	44	8	10	68	9
1999	0	0	16	0	40	19	12	9	21	21
2000	0	0	12	0	0	28	1	1	46	18
2001	0	0	6	0	0	31	25	7	27	12
2002	0	0	2	0	0	0	10	10	41	5
2003	0	0	10	21	0	0	15	7	25	8
2004	0	0	2	0	0	0	28	4	22	6
2005	0	0	0	12	0	6	1	3	25	9
2006	0	0	6	0	0	10	1	1	23	5
2007	2	2	1	0	0	11	1	0	26	1
2008	7	0	4	1	0	6	10	3	13	3
2009	0	0	0	0	0	14	0	3	0	0
2010	2	6	4	0	0	62	0	2	38	8
2011	11	3	5	0	3	63	1	14	39	37
2012	16	1	0	0	1	19	2	3	16	11
2013	16	1	4	0	174	31	2	8	20	18
2014	20	157	3	2	33	14	1	2	19	22
2015	36	101	6	0	0	23	0	0	33	0
2016	39	133	9	0	0	10	0	0	59	0

▶ Source: IFR 2017 (refers to ISIC (Rev. 4) 13, 14 and 15: Textiles, wearing apparel, fur, leather, leather products and footwear). Available at: https://ifr.org/worldrobotics.

These are Sewbo, SoftWear Automation and Grabit. This enables one to come to a clearer sense of the technological bottlenecks involved than is possible by a global assessment of hundreds of occupations, valuable as that approach may be in its own right. At the same time, a high degree of automation is possible in apparel sewing even when fabric handling is largely done by hand. In this regard, we also look at MAICA, a company producing semi-automated machinery to sew shirts.

Sewbo.[17] Sewbo's approach makes use of conventional, off-the-shelf collaborative robots and sewing machines. Its innovation is not with automation machinery but rather in the treatment of pieces of fabric, making them temporarily rigid with a water-soluble chemical. After being treated with the chemical, the stiffened pieces of fabric can be provisionally joined with an ultrasonic welder (commonly used to join plastic parts) in preparation for sewing, or directly manipulated through a sewing machine by a robotic arm with a suction cup hand. After being sewn, the article of clothing is then rinsed in water, removing the stiffening chemical. In short, Sewbo's approach is to make pieces of fabric similarly manipulable to pieces of metal, thus making apparel sewing akin to a conventional assembly operation that is able to take advantage of the ready reprogrammability of state-of-the-art collaborative robots. Such reprogrammability could, in principle, accommodate the rapidly changing demands of the fashion industry.

Sewbo claims to be the first company to sew a complete article of clothing, a basic T-shirt. There are some intrinsic limitations to Sewbo's approach in that it cannot work with material that would be damaged by soaking in water, nor with waterproof fabric. One textiles and apparel researcher has also expressed reservations about the economic viability of the Sewbo approach, given the costs of the extra steps involved in treating fabrics as well as of chemicals and water. As of 2016, Sewbo was literally a one-man operation, yet it also had a pilot project with Bluewater Defense, which produces uniforms for the US military. Important in this regard are rules dating from 1941 requiring that the US Department of Defense purchase uniforms produced in the United States. Such considerations can make attractive investments in sewing robots that would not be otherwise profitable, at least for this sizeable captive market, especially in light of the relatively high labour costs as well as the scarcity of skilled operatives in the United States.

SoftWear Automation.[18] SoftWear Automation is a collaboration with the Georgia Institute of Technology and was supported by an over US$ one million grant from

17 Sources for Sewbo: Sewbo website: http://www.sewbo.com/; Brewster 2016; Bhattacharya 2016; Kavilanz 2016.

18 Sources for SoftWear Automation: SoftWear Automation website: http://softwearautomation.com/; *The Economist* 2015; Stacey and Nicolaou 2017; *The Boss Magazine* 2015; McGregor 2015; Fenigsohn 2016; Scibetta 2016; Allinson 2016; Bhattacharya 2016; Bain 2017a; Grossman 2017; Barrie 2017; Guizzo 2018; Quinn 2019.

the US Department of Defense, whose vested interest in the development of sewing robots is noted above. In contrast with Sewbo, SoftWear Automation designs and builds robots specifically for sewing – Sewbots, the company calls them. The company deals with the challenges posed by the pliability of fabrics through the development of sensors and accompanying visual enhancement software that count individual threads and intersections of threads in fabric. These sensors enable its robots to guide fabrics through conventional sewing machines with a high degree of precision, and the company has also developed robotic sewing machines. Between different sewing operations, pieces of fabric are conveyed along flat surfaces by hovering over small air jets or being slid by robotic arms. SoftWear Automation's systems are able to import files from commonly used pattern design software, facilitating just-in-time product customization and changeovers.

The company's robots are able to perform discrete sewing operations, such as sewing buttonholes or two pattern pieces of denim jeans. The company claims, though, that full-line automation for jeans and button-up shirts is in the offing and has reportedly received US$two million from Walmart for a project to automate the production of jeans. Referring specifically to SoftWear Automation, Walmart's optimistic assessment is that sewing robots will result in "the reshoring of apparel manufacturing in the U.S., and other high labor markets, cutting lead times to consumers, creating in-demand, highly-skilled jobs, and freeing manufacturers from the endless search for low-wage labor" (quoted in Scibetta, 2016).

A key development for SoftWear Automation is the use of its sewing robots in a T-shirt factory which was planned to open in the United States in late 2019. Tianyuan Garments, a large Chinese contract manufacturer producing primarily for Adidas, has reportedly invested US$20 million in this factory, which will produce T-shirts in 21 fully-automated production lines supplied by SoftWear Automation. It is claimed that costs per T-shirt will rival those of T-shirts produced in such low-wage countries as Bangladesh. Yet this depends on the number of T-shirts produced in a given amount of time, and here published estimates vary widely.[19] While the production lines may be fully automated, it is also reported that the factory will create 400 jobs ancillary to sewing T-shirts. Even if direct production costs were higher than in low-wage countries, the other significant cost and time advantages associated with reshoring noted above could more than offset this, though these may hold less for relatively standardized, low-cost items like T-shirts. After T-shirts, SoftWear Automation intends

19 The Chairman of Tianyuan garments is quoted as saying that the production lines could produce one T-shirt every 22 seconds and 800,000 T-shirts per day (Barrie 2017; see also Grossman 2017). Yet even if each of the 21 production lines produced one T-shirt every 22 seconds and ran 24 hours per day, this would be equivalent to just over 80,000 T-shirts per day. Nor is it evident how to reconcile this lower, though still very impressive, daily production figure with other reported estimates that the 21 production lines could produce 1.2 million T-shirts per year, which could be achieved in just 15 days of production at 80,000 T-shirts per day (Bain 2017a). Moreover, other sources report that the 21 production lines could produce 23 million T-shirts per year (Guizzo 2018).

to diversify into the production of jeans, dress shirts and uniforms. The potential implications of its sewing robots for reshoring and the structure of global supply chains is one of SoftWear Automation's selling points, with its website stating that: "SoftWear's fully automated Sewbots allow manufacturers to SEWLOCAL™, moving their supply chains closer to the customer while creating higher quality products at a lower cost." Also telling is the closing caption to the company's demonstration video for T-shirt production: "Redesigning the textile supply chain."

Grabit.[20] Grabit developed a robotic hand that uses electroadhesion (a type of static electricity) and can pick up and handle a wider range of objects – including fabrics – than conventional robotic gripper or section cup hands. When combined with a customized Toshiba Machine robot, Grabit's hand is reportedly able to arrange the pieces for a sports shoe upper 20 times faster than a human, after which the pieces are heat-fused. Investors in Grabit include Nike and the Esquel Group, a large manufacturer of button-up shirts for the likes of Ralph Lauren and Tommy Hilfiger that intends to use the technology to make collars and cuffs. Nike is reportedly installing about a dozen Grabit machines in shoe factories in China and Mexico. Nike's interest in Grabit is motivated at least in part by its interest in shifting production closer to customers in Europe and the United States, with an article in *Bloomberg News* noting that "Automation factors heavily into Nike's plan to move factories closer to the U.S." (Brustein 2017).

MAICA.[21] MAICA is an Italian-based company that has been in operation since 1977 and that specializes in manufacturing computer-controlled, semi-automated machinery to sew button-up shirts. MAICA was acquired by Jack Sewing Machine, a Chinese company, for €6.5 million in late 2017. According to MAICA's website, the company has four product lines, focusing on collars, cuffs, button fronts and folding machines. Rather than attempting to overcome the challenges posed by the pliability of fabrics, as with Sewbo and SoftWear Automation, the company's strategy is rather to work within these constraints, with workers hand-feeding fabrics into a series of machines that break down the shirt-making process into discrete steps. Each machine is specialized for each step, with some of steps using conventional sewing machines integrated with MAICA's auxiliary machinery.

It might be thought that MAICA's semi-automated approach represents a transitional stage towards fully automated production, but there are good reasons to think otherwise. In Mercedes-Benz and BMW, for example, there has been an increased use of collaborative robots in recent years, with workers working side-by-side with these

20 Sources for Grabit: Grabit website: https://grabitinc.com/; Brustein 2017; Bain 2017b; *The Robot Report* 2018.

21 Sources for MAICA: MAICA website: http://www.maicaitalia.com/company-profile/; *Apparel Views* 2017; demonstration videos available at: https://www.youtube.com/watch?v=sv536cciOiQ; https://www.youtube.com/watch?v=bclBH1o84Tk.

smaller, safer and more readily adaptable robots (Gibbs 2016; Tobe 2016). One study of a BMW plant found that assembly lines with cobots working alongside workers are more efficient than lines with either workers or robots alone, and this combination is also argued to be better able to accommodate the customized options demanded by customers. Cobots are reported to soon become the largest selling type of industrial robot (Tobe 2016). While MAICA's machines may not be robots in the strict sense, the approach of workers working alongside computer-controlled machines may represent a viable path for automation in the apparel industry, perhaps complementing more fully-automated approaches. In this sense, automation in the apparel industry may follow a more evolutionary than revolutionary path, based on incremental improvements and application to a wider range of apparel products. MAICA's approach also has the virtue of being market-tested, with their machines being used, for example, in a Zara factory in Portugal – and thus within the European fast fashion market – as well as a shirt factory in Sri Lanka, with each factory reportedly producing thousands of shirts a day. From the employment perspective, the labour-displacing effects and reshoring potential of such semi-automation may also be considerable, whether or not it uses robots.

2.3. 3D printing

Apparel. 3D printing is an automated process in which a 3D printer – effectively a computer-controlled industrial robot – converts a virtual object into a tangible object through the additive application of materials. The more technical term for 3D printing is additive manufacturing, and the American Society for Testing and Materials (ASTM) classifies seven distinct additive manufacturing processes.[22] Diverse materials can be used for 3D printing, and so technological developments relevant to the apparel and footwear industry depend on technological developments in materials science. 3D printing can also break down the distinction between textile production and apparel production, effectively merging the two, and may come to be used more for prototyping than factory production. The diversity of processes, materials and outputs make it particularly challenging to get a sense of the direction of technological developments and subsequent implications for employment in developed and developing countries. One industry analyst offers the following assessment, providing a sense of the technological bottlenecks involved:

> Due to their inherent structures, metals and hardline goods are currently better suited to 3D printing. Anything with reliable rigidity is a target for three-dimensional prototyping and all the potential that comes with, but it's the inherent flexibility, drape, hand and so on that make a garment actually wearable. Is this something we expect to be able to recreate with 3D printing in the near future? Unforeseen advancements aside, I do not personally believe that the 3D printing of soft garments is likely any time soon. Working with the kinds of materials we currently use to create clothes is just too complex … (Le 2015)

22 Available at: https://www.astm.org/Standards/additive-manufacturing-technology-standards.html.

As with automated sewing, a key technological bottleneck has to do with the pliability of fabrics as well as the challenges of developing breathable fabrics that are durable enough to withstand a washing machine. Yet leading fashion design institutes provide resources for 3D printing and recent fashion shows have been devoted to 3D printed apparel, indicating considerable interest in the technology (Mau 2014). Also striking is the number of technological and commercial "firsts" in the 3D printing of apparel in recent years. Continuum is reportedly the first company to market 3D printed apparel, nylon bikinis made to customers' specifications and measurements conveyed through the company's website (Hennessey 2013). Materialise is the first company to produce printable material for fabric that is both pliable and durable (Rietveld 2013). Stratasys is the first company to combine two different printable materials, one hard and one soft, in a single printed garment. XYZ Workshop produced a 3D printed dress made from a recyclable, flexible bioplastic made from corn and released the design files so that others can reproduce the dress (Dagirmanjian n.d.). Electroloom developed a 3D printer that has produced prototype T-shirts and tank top shirts (Luimstra 2014). prospective developments include so-called bio printing which would enable the creation of printable simulations of such natural fibres as cotton and silk, as well as incorporating conventional cotton into 3D printing processes (Rietveld 2013; Luimstra 2014).

Footwear. In terms of being commercially marketed particularly by the big brands, 3D printing has made greater headway in footwear than apparel, particularly athletic footwear. Indeed, there is at least one online store that specializes in sales of 3D footwear.[23] Nike, Adidas and New Balance now sell footwear with 3D printed soles. Yet the more labour-intensive processes in footwear production is not the production of soles (which are commonly injection molded), but rather the production of uppers. A key innovation in the production of uppers has been Nike's Flyknit footwear, not 3D printing but rather the machine knitting of uppers. A key reason that Flyknit footwear is touted has to do with the physical properties of the upper, combining the fit and light weight of a knitted sock with the support of a traditional upper. Nonetheless, producing Flyknit footwear reportedly requires only half the labour of traditional athletic footwear (Thomasson 2015). At present, Flyknit technology is primarily used in Nike's high-end athletic shoes, and most of the company's shoes continue to be made from sewn or heat-fused uppers. A Seattle-based company, Prevolve, does make running shoes with 3D printed uppers and soles called Biorunners that are custom-made for each customer's foot and running style. Yet these too are premium running shoes, selling for around US$250.[24]

In terms of reshoring, one of the more interesting cases is the rise and fall of Adidas' Speedfactory (Agence France Presse 2016; Roazen 2016; Wiener 2017; Ismael 2018;

23 Available at: https://3dshoes.com/.

24 Available at: https://www.pre-volve.com/biorunners.

Bain 2019). Speedfactory was initially part of Adidas' Made for Germany (MFG) initiative, which had the explicit objective of bring production closer to customers in Europe and the US. Shoes from the first Speedfactory in Germany hit markets in 2016 and from the second Speedfactory in the United States in 2018. The technology used in these factories included a combination of 3D printing, robotics, and automated knitting, as well as computer simulation and modelling for developing new designs and producing custom-fitted running shoes. Since these factories were owned and operated directly by Adidas, they represented a counter to the broader trends of outsourcing as well as offshoring. The reasons provided by Adidas for such a move are the familiar ones regarding reshoring: reduced time between design and production and faster delivery times more generally, reduced transport costs, and concerns about rising labour costs in Asia. The Adidas Vice President of Design maintained that the Speedfactory initiative would not result in fewer jobs in the company's supply chain, given that the market for footwear is rapidly expanding, stating that "with each Speedfactory, we're looking at around 150–160 new jobs … And this is all supplementing our existing supply chains and not really replacing them" (quoted in Roazen 2016). In a striking turnabout, Adidas announced in November of 2019 that it would shut down the Speedfactory in both Germany and the United States in early 2020 and move the associated technologies to factories in Asia. The reasons given by Adidas are closer proximity to the vast majority of its suppliers and that factories in Asia were more flexible in producing a wider range of products beyond running shoes with knit uppers.

2.4. Summing up: Jobs created, jobs lost, and the global division of labour

The implication of Frey and Osborne's study and other studies using their method is that it is technologically possible for there to be massive job losses in the apparel industry in coming years resulting from computer-controlled automation technologies. In such a scenario, the competitive advantage of developing countries in terms of lower labour costs would be weakened, all the more so in light of the cost and time advantages resulting from the closer proximity of production and consumption. There would be substantially reduced employment for a given quantity of apparel output, accompanied by the reshoring of production towards developed countries alongside the persistence of production in large developing country markets, most notably in China. Even in the face of a rapidly growing market for apparel, the net effect of such sweeping labour displacement on global employment in the industry would appear negative, based on Frey and Osborne's extremely high estimates of the risk of automation in relevant occupations. In such a scenario, the negative labour displacement effects of automation on employment at the task and establishment levels are unlikely to be offset by positive market expansion effects at the industry level.

The possibility of such a scenario is also suggested by the views of management at Sewbo and SoftWear Automation. A quotation from a published interview (McGregor 2015) with the CEO of SoftWear is illustrative and also sheds light on the new skills required in automated apparel sewing:

> All the systems are monitored with our software and *the only real human interaction* is around materials management and resupplying the machines. As sewing jobs left the U.S., the knowledge left with it. When these jobs return thanks to robotic solutions, there will be a different kind of knowledge and training required. These will be robotics-type jobs, as opposed to straight seamstress work. As the market continues to adopt our technology, getting the right training to this new form of knowledge worker will be our key challenge [emphasis added].[25]

It is worth emphasizing that new automation technologies may have negative effects on workers in addition to job loss. For the threat of automation can also be used to curtail workers' demands regarding working conditions and pay. An example is given in a recent article in the *Wall Street Journal*, in which a union leader in Bangladesh stated that factory owners threatened to automate jobs if workers would not agree to management's plans (Emont 2018).

In our discussion of MAICA, we suggested that the future of technology in the industry may well be represented by a more collaborative engagement between workers and machines, as suggested as well by the increased use of cobots in such firms as Mercedes-Benz and BMW. If this is true, then the prospects for employment in the industry would be very different. There still may be significant reshoring, but the net effect on global employment in the industry is less clearcut. And contrary to the expectations about the need for higher-skilled workers noted above, the semi-automated approach may actually require fewer skills and less training than traditional sewing. Production line workers are, after all, largely involved in feeding fabrics into automated sewing machines. This is suggested, for example, by MAICA's website, which states, "A remarkable ease of use allows everyone to use them without difficulty, being able to explore all the features from the very first use."[26] At the same time, MAICA's equipment is all computer controlled, and clearly there are more skilled jobs involved in setting up and adapting this equipment.

It is challenging enough to get a sense of the implications of automated sewing for employment and the global division of labour in the industry, particularly the extent to which long-standing trends of offshoring as well as outsourcing might be significantly

25 In a similar vein, the CEO of Bluewater Defense with whom Sewbo is collaborating stated the following in an interview: "I'm very concerned about what automation means for jobs. But without technology, the industry will die. Automation is happening in almost every industry. So it's incumbent upon us to start training and retraining workers for the next generation of tech-focused manufacturing jobs" (quoted in Kavilanz 2016).

26 http://www.maicaitalia.com/company-profile/.

offset by these technologies. This seems all the more so for 3D printing, for which one must account for the range of additive printing processes as well as developments in materials sciences, and for which the current pace of change is manifested in a rapid succession of technological and commercial “firsts”. Whereas automated sewing is largely about making old products in new ways, 3D printing typically involves the creation of new products, or at least significant variations of old products. That is, 3D printing encompasses both process *and* product innovation.

There is little question that 3D printing will play an important role in prototyping and making custom-made products for the high-end market niche, even enabling consumers to create one-off 3D printed products within their own homes. Less clear at present but more fundamental to the question of reshoring is the extent to which 3D printed apparel and footwear products will cater to the mass market, competing against comparable products produced in low-wage countries. As with automated sewing, this is not just a question of technological feasibility but also economic feasibility, that is, a question of relative cost compared to more conventional alternatives. Such a consideration must take into account not just relative labour costs but also capital costs and the rapid capital depreciation that is likely to occur in the face of rapid technological change and technological obsolescence.

It is important to emphasize that economic feasibility does not mean that the unit costs of production of either 3D printing or automated sewing need to be equal to or less than comparable goods produced in low-wage countries. For the closer proximity of production and consumption brings with it a host of other cost and time advantages that can offset higher unit costs of production. This is all the more so in so far as closer proximity enables just-in-time production characterized by leaner inventories and lesser reliance on the deep price markdowns that have plagued the industry. At the same time, the dashed expectations of Adidas’ Speedfactory initiative in Germany and the United States provides a cautionary tale for the reshoring hypothesis, in which proximity to suppliers in Asia (among other factors) outweighed proximity to consumers in Europe and the United States.

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3 The electronics industry

Fernanda Bárcia de Mattos*

3.1. Introduction

One of the largest industries in the global economy, electronics generates more revenue than any other goods-producing sector and accounts for nearly one-quarter of traded manufactured goods globally (Sturgeon and Kawakami 2011; Plank and Staritz 2013). The value of global electronics exports has more than tripled since the mid-1990s, surpassing US$2 trillion in 2017.[27] Electronics is also a big employer: it is estimated that over 18 million workers across the globe are engaged in the industry (Raj-Reichert 2016).

Limited need for co-location between engineers and production means that a single product, such as a mobile phone, can contain parts from several firms across multiple countries. Greater tradability has led to extensive offshoring, especially of lower value-added activities, such as assembly, towards lower-cost countries. In the past quarter-century, Eastern Asia, especially China, and more recently South-Eastern Asia have gained prominence as manufacturing centres, while high value-added core activities such as R&D remained in Western Europe and the United States (Sturgeon and Kawakami 2011; ILO 2014).

Indicative of the global reshuffling of production, table 3.1 shows formal employment and exports in 2000 and in (or around) 2015 for the top ten exporters of electronic products in 2015, as well as their shares of global exports. Accounting for over 90 per cent of global electronics exports, these countries employed 14.5 million workers in the industry in recent years, over 80 per cent more workers than in 2000. The trends show significant offshoring, with a growing share of exports and greater employment in middle-income countries. Combined, the five emerging countries' share of electronics exports increased from 26 to 58 per cent, while their share of employment

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27 Electronics products include those under the Standard International Trade Classification (SITC), Rev.3 divisions 75, 76 and 776 (*WTO Trade Profiles Database*).

among the main electronics exporters expanded from 53 to 77 per cent. China alone accounted for 47 per cent of global exports in 2015, up from 15 per cent in 2000, and employment nearly tripled.[28] Employment also increased manifold in Viet Nam and Mexico, but whereas the share of exports rose for the former it remained stable in the latter. In Thailand, employment expanded but the export share held steady, while both declined in Malaysia. In contrast, the export share of the top high-income countries decreased from 67 per cent in 2000 to 38 per cent in 2015, and their share of employees contracted from 47 to 23 per cent. Declines were most marked in the EU countries, Japan and the United States.

Despite these trends, there are concerns over the possibility of reshoring from emerging to high-income countries. As electronics manufacturing has been pivotal in countries' economic development processes, reshoring could have important implications for future development prospects.

Consulting firm A.T. Kearney (2014, 2015) documented that approximately 11 per cent of the 700 reshoring cases to the United States between 2011 and 2015 were in the electronics industry. Reshoring is often associated with rising labour costs in emerging countries, growing need for skilled labour in production processes, faster turnaround times, lower transportation costs, concerns over intellectual property, and increased flexibility (see also Montalbano 2015; Regole 2015; Cohen et al. 2016). Proximity to end markets reduces inventory needs, and allows companies to produce as needed in response to short-term market trends. At the same time, in electronics specifically, A.T. Kearney suggests that offshoring – to China and other Asian countries as well as nearshoring to Mexico – continues to outweigh reshoring.

Ultimately, location choices made by profit-seeking entities are complex decisions which consider, among other factors, the potential of new automation technologies and whether reshoring would trump emerging countries' low-cost labour advantage. Importantly, the production of electronics involves distinct processes in the manufacture of components and the assembly of final products, each with unique technological needs and bottlenecks. This study focuses mainly on electronics assembly as this is predominant in emerging and developing economies. The next section examines automation technology in electronics manufacturing. It analyses trends in robot usage and outlines technical bottlenecks and recent advancements, with a focus on assembly. Following, a more nuanced view of industry dynamics is given through a closer look at two large players. The last section summarizes findings and presents concluding thoughts.

28 China includes Taiwan and Hong Kong.

▶ Table 3.1. Exports and formal employees in top ten electronics exporters, 2000 and 2015 or latest year

Top 10 economies (5 categories)	Share of global exports in 2000	Share of global exports in 2015	Exports in 2015, billions of dollars	Employment in 2000[1]	Employment in 2015 or latest year[2]
China (incl. HK and Taiwan)	15,0	47,4	935	3 507 848	9 868 596
Mexico	3,4	3,2	63	28 222	250 275
Malaysia	5,2	3,0	59	402 470	368 737
Viet Nam	0,1	2,4	47	18 591	410 994
Thailand	1,9	1,8	35	214 103	297 630
Total: Developing	25,6	57,8	1 139	4 171 234	11 196 232
European Union (28)	28,0	16,3	322	1 254 444	1 092 970
United States of America	15,2	7,2	141	1 008 717	943 767
Singapore	7,3	6,0	119	102 320	79 680
Korea, Republic of	5,6	5,8	110	327 218	546 357
Japan	10,7	3,1	60	989 846	627 677
Total: Developed	66,8	38,4	753	3 682 545	3 290 451

▶ Notes: [1] China, 2003. [2] China, 2014; EU, 2015, includes latest year for Ireland (2012) and Slovenia (2014), and excludes Luxembourg and Malta; Japan, 2013; Mexico, 2013; Thailand, 2011; Viet Nam, 2014.

▶ Sources: WTO 2017 : refers to SITC (rev. 3) 75, 76 and 776: Electronic data processing and office equipment, telecommunications equipment, integrated circuits and electronic components; UNIDO 2017: refers to ISIC (rev. 3) 30 and 32: Office, accounting and computing machinery, radio television and communication equipment.

3.2. Automation in electronics manufacturing

Many of the jobs in electronics assembly are low-skill, repetitive, manual jobs, often deemed the type most susceptible to automation based on existing and emerging technologies. One of the most widely cited estimates of the potential impact of automation technologies on jobs is that of Frey and Osborne (2013, 2107). As outlined in Chapter 1, that study attributes automation probabilities to over 700 occupations based exclusively on an assessment of technological feasibility according to the occupations' task characteristics. This method associates high risks of automation for the majority of workers in electronics assembly manufacturing, including 84 per cent for electrical and electronics engineering technicians, and 95 per cent for electrical and electronic equipment assemblers.[29] Consequently, 63 to 81 per cent of salaried workers in electrical and electronics manufacturing in Indonesia, Philippines, Thailand and Viet Nam are at high risk of automation.[30] These and other estimates of technological unemployment have featured in news articles across the globe, raising concerns over the future of employment.

And indeed the electronics industry has been a leader in technology adoption. In 2016, 13 per cent of all industrial robots sold globally was for the electronics industry, equivalent to the industry's share of the total stock of industrial robots (table 3.2). Research by the International Federation of Robotics (IFR 2018) suggests that, together with the electrical industry, the electronics industry will continue to drive robot use in coming years and may surpass the automotive sector in the number of installed robots by 2021. It is worth noting that the vast majority of the purchases and stock of robots for the electronics industry is accounted for by high-income countries. The top electronics exporters shown in table 3.1 concentrated over 95 per cent of the global stock of robots in the industry in 2016, 75 per cent in high-income countries, in sharp contrast to 23 per cent in middle-income countries – 22 per cent of which is accounted for by China.

A contraction in employment and an increased ratio of robots per thousand workers in the electronics industry of high-income countries – e.g. doubling in Europe and tripling in the United States between 2005 and 2015 – suggests that some automation has occurred in these countries. In contrast, technology adoption was much slower and employment expanded in emerging countries, though trends diverged. For emerging countries such as China and Malaysia the robot/workers ratio increased significantly. In contrast, employment growth outpaced robot adoption in Viet Nam and the ratio of robots per thousand workers declined. This is connected to the

29 In contrast to 1.1 per cent for mechanical engineers and 2.5 per cent for electronic engineers (except computers (Frey and Osborne 2013, 2017).

30 Refers to electrical and electronics and does not strictly correspond to the electronic category used in this study (Chang, Huynh and Rynhart 2016).

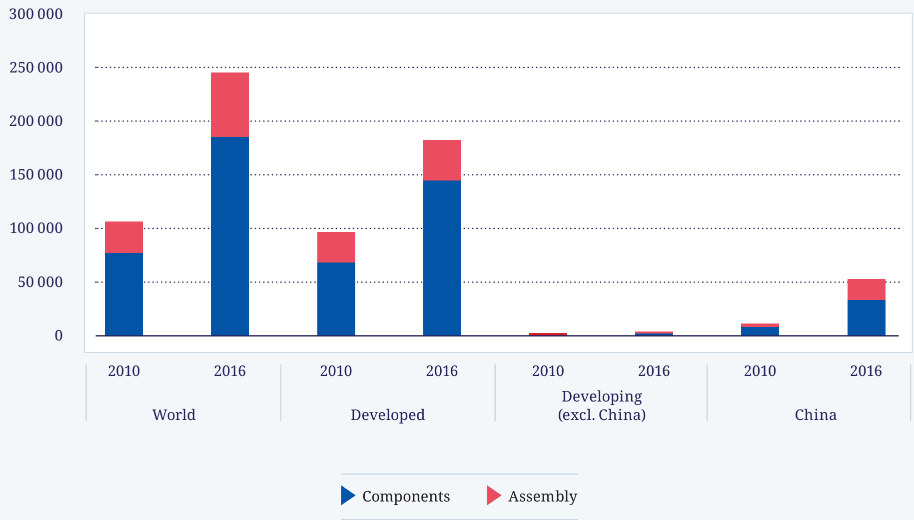
▶ Table 3.2. Global robot sales and stock in electronics (units) and share of total (per cent), 2000–2016

	Annual robot sales	% of world total sales	Annual robot stock	% of world total stock
2000	5 378	5,5	59 732	8
2001	1 829	2,3	53 466	7,1
2002	336	0,5	47 828	6,2
2003	735	0,9	41 402	5,2
2004	1 861	1,9	39 489	4,7
2005	15 383	12,8	48 674	5,3
2006	11 921	10,7	42 074	4,5
2007	11 017	9,7	42 191	4,2
2008	13 604	12	47 281	4,6
2009	8 669	14,4	49 165	4,8
2010	24 406	20,2	106 081	10
2011	22 315	13,4	126 138	10,9
2012	23 931	15	148 509	12
2013	21 613	12,1	163 876	12,3
2014	29 988	13,6	185 702	12,6
2015	36 064	14,2	211 807	13
2016	39 472	13,4	242 936	13,3

▶ Note: Electronics include ISIC (rev. 4) 260-263: electronic components/devices, semiconductors, LCD, LED, computers and peripheral equipment, information and communications equipment domestic and professional without automotive parts.

▶ Source: IFR 2017.

▶ Figure 3.1. Stock of robots by subsector and income group of the world, and the top ten electronics exporters in 2015



▶ Note: US includes Canada and Mexico until 2010; EU-28 excludes Cyprus and Luxembourg.

▶ Source: IFR 2017.

traditional international division of labour whereby lower-value labour-intensive processes are carried out in emerging and developing economies while higher-value capital-intensive activities are centred in high-income countries.[31]

Figure 3.1 shows the stock of robots in the electronics industry by subsector, i.e. components and assembly, for the world and for the largest exporters (as in table 3.1).[32] Two important facts emerge. First, the vast majority of robots are concentrated in developed countries. Emerging countries (excluding China) have modest stocks of robots. Second, the marked increase in the stock of operational robots in the electron-

31 Recent research by the World Economic Forum (WEF 2018) concluded that innovation hubs in high-income countries accounted for over half of the value-added generated by the consumer electronics value chains in 2017, though they only employed 16 per cent of the consumer electronics labour force. In turn, China and developing countries employed over 85 per cent of workers, largely in lower-value production work.

32 Components relates to ISIC (rev. 4) codes 260-1 (manufacture of electronic components and devices, semiconductors, LCD, and LED) whereas assembly encompasses codes 262-3 (computers and peripheral equipment, information and communications equipment domestic and professional without automotive parts), as defined in IFR 2017.

ics industry was driven by an upsurge in robots for the production of components. Worldwide, there are over three times as many robots used in production than the assembly of electronics components. In the top high-income exporters, the ratio of robots for electronics components to assembly reaches nearly four. Robots for the production of electronics components comprised 67 per cent of all industrial robot purchases in the industry between 1996 and 2016. In 2016, such robots accounted for over 75 per cent of the industrial robot stock in the electronics industry.

Production processes and the state of automation in electronics is distinct between the manufacture versus assembly of components. This distinction can be exemplified by the production of memory cards or USB flash drives. The fabrication of memory chip wafers is a sophisticated and highly automated process in ultraclean environments where contamination and errors are associated with high costs. These technology-intensive facilities are largely located in high-income countries. In turn, final products such as memory cards are assembled through labour-intensive processes in low-cost locations (McKinsey 2017; Platzer and Sargent 2016). Why are there relatively few robots in electronics assembly? The assembly of electronic products necessitates handling small and fragile parts, put together in compact, tightly-packed products. In addition, rapid technological progress has led to short product life-cycles. These bottlenecks create the need for adaptable and reusable robots fitted with force and vision sensors to improve the handling of miniaturized parts, allowing costs to be amortized over longer periods of time.

Increasingly, robot manufacturers are developing new solutions. Flexible robots are at the forefront of these trends, both in terms of traditional and collaborative robots (or cobots). Flexible robots are typically a robotic arm with multiple axes of movement and interchangeable heads that can perform a variety of tasks (Roehl 2017; Shakely 2014). These robots are usually configured with a series of sensors which, together with flexibility of movement, allow for quick reprogramming and reconfiguration and, in the case of cobots, remove the need for safety barriers between machines and workers. Vision sensors and high-precision grippers allow for greater accuracy in the picking and placing of parts, permitting flexible feeding solutions in response to the challenges of the unsorted presentation of parts, which remains a barrier to electronics manufacturing automation. In turn, force sensors are ever more important as electronics miniaturize and delicate parts need to be handled. Force sensors improve tactile feedback and allow robots to “feel” their way into assembly, adjusting force in response to a dynamic assembly process, according to Christopher Blanchette of FANUC Robotics America Corp (quoted in Brumson 2011).

Most leading robot manufacturers now offer collaborative robots, frequently targeting electronics assembly. In 2014, ABB launched YuMi, a two-arm cobot designed specifically to handle small parts such as mechanical components for smartphones, tablets and other consumer electronics (Anandan 2015). Kuka’s LBR iiwa allows for the automation of complex assembly tasks and direct cooperation with workers and is advertised as a solution to electronics manufacturing. Other firms such as Rethink Robotics and Universal Robots also produce and market cobots specifically for use in the electronics industry.

These and other machinery manufacturers also continue to develop smaller and lighter traditional industrial robots for the electronics industry. In 2016, Kuka launched KR 3 Agilus, which involved Chinese electronics manufacturers in the development phase with the intention to target electronics manufacturing in the Chinese and Asian markets (Kuka 2017). Kuka's robot can, for instance, fasten screws with a diameter head of 1.4mm, common in mobile phones and other hardware, as well as test keyboards, which is traditionally done manually by workers. There is also a new generation of four axes selective-compliance-articulated robot arms (SCARA) and other types of robots for use in electronics assembly (Sprovieri 2018). This new generation of robots can increasingly perform tasks such as mounting small objects, gluing, setting very small screws in place, tending machines and testing circuit boards, among others.

But technological feasibility is only one of many factors in a firm's decision to adopt automation technologies. Economic considerations include whether automated methods would be at least as profitable as current methods of production, including the cost of purchase, installation, operation and maintenance of machines relative to the cost of labour. Fragmented production processes and the complex structure of the electronics global value chain, marked by widespread outsourcing and subcontracting, also have an impact on decisions on technology adoption. Branded firms, contract manufacturers and component suppliers have different capabilities and motivations for investing (or not) in automation technologies.

Unlike other industries such as apparel and footwear, the assembly of electronics is carried out by a small group of large contract manufacturers which, according to the European Commission, account for approximately 80 per cent of global outsourced electronics production (EC, IHRB and Shift 2014). These large firms may have incentives (and capacity) to invest in innovation, being able to capture gains associated with productivity increases. However, these investments have been inhibited by the technological bottlenecks associated with the nonflexible robot solutions outlined above, as well as by economic considerations and an abundance of cheap labour. To date, assembly robots are highly concentrated in a few countries. The three largest markets between 1996 and 2016 purchased 90 per cent of all electronics assembly robots over these two decades, namely China (including Hong Kong and Taiwan), Japan and the Republic of Korea. In addition, with the exception of China and Malaysia, middle-income countries which rank amongst the main electronics exporters are not amongst the top markets for assembly robots. Overall, the number of robots in middle-income exporters (except China) remains very limited, and the industry remains labour-intensive.

3.3. Electronics manufacturing, automation and reshoring: Telling cases

To better understand the state of the industry and how it has evolved in the past few years, we explore publicly available information on two large players. Looking beyond task and occupation-based automation risk assessments, the examination of developments in the production strategies of Hon Hai Precision Industry (i.e. Foxconn) and Samsung Electronics allows for a better grasp of the extent to which technology has been adopted in electronics assembly and whether there are signs of a rearrangement of global production.

Foxconn. Foxconn is the world's largest electronics contract manufacturer, with over one million workers (Harris, Kimson and Schwedel 2018). The company's interest in automation led it to announce in 2011 plans to deploy one million robots in the following three years and, by 2015, it had an estimated 50,000 robots in operation (Clapaud 2015; Economist Intelligence Unit 2018). The push towards automation continues. Foxconn's handbook for the 2018 general shareholder's meeting reveals plans to invest over US$300 million in the Internet of Things, artificial intelligence, and robotics research in the next five years (Hon Hai 2018).

There have also been reports of significant technology-driven layoffs. A recent study for Bain & Company reports that Foxconn replaced 60,000 factory workers with robots due to declines in robot prices and higher wages in China, though there is scepticism of whether these were indeed related to automation (Harris, Kimson and Schwedel 2018). Foxconn's general manager for automation technology, Day Chia-peng, stated in a recent interview: "The majority of our production lines employ a mix of automated stations and manual operations for the various process steps and we expect this to remain the case for the foreseeable future" (Economist Intelligence Unit 2018). This suggests that significant technological bottlenecks in assembly remain and that instead of full automation, new technologies will lead to teams of robots and workers.

Although the majority of its production capacity is in China, Foxconn has taken steps to invest in production in high-income countries. In July 2017, Foxconn signed a memorandum of understanding (MoU) with the Government of Wisconsin in the United States, announcing plans to invest US$10 billion and create up to 13,000 jobs (Horowitz 2017). It is, however, unclear whether the plans will materialize. In early 2019 it was reported that Foxconn was reconsidering plans to build a LCD display factory, citing high costs of assembly in the US and suggesting it would instead invest in an R&D facility (Paquette 2019). At the same time, the firm has also made plans to continue to invest in emerging economies. For instance, in August 2015, Foxconn signed an MoU with the Maharashtra Government in India, to invest US$5 billion, creating a minimum of 50,000 jobs within five years (Aulakh 2016). Early 2018 reports indicated that the promise had not yet concretized, even though the firm had invested in other parts of the country (Aulakh 2018). More recently, in 2019, several news articles reported that Foxconn was making further investments in India and would start to produce iPhones in the country (Yang, Kubota and Purnell 2019; Mankotia 2019).

Samsung Electronics. Unlike many of its competitors, Samsung Electronics retains significant manufacturing capacity. The company owns and operates several factories and thus relies less on outsourcing than many firms in the industry. Publicly available information on the firm's mobile phone production suggests it may not yet make economic sense to automate assembly. It is reported that the majority of production takes place in emerging countries – including Brazil, China, India and Viet Nam – with only about 8 per cent of phones estimated to be manufactured in the Republic of Korea, in spite of very advanced technological capabilities in Korean facilities (Jin-young 2015; O'Leary 2016). According to recent reports:

> Manufacturing in Gumi [Republic of Korea] is more robotic than assembly by hand: It takes just 13 minutes for 14 giant machines to join a circuit board and battery, slip it behind a display, and seal it all into a glass and metal housing. It takes 30 minutes total to make the phone, counting the time required to install the operating system. In that time, only two or three people actually handle any given phone. Instead, it's robot arms that grab components, robot noses that sniff for signs of organic compounds, traces that batteries might be failing. We see a robot cart hauling parts down a corridor, following a path made of silver reflective tape. It plays a tune, and pauses when we get in front of it. (Kaplan 2017)

It appears, therefore, that technological advancements could allow for a higher degree of automation in mobile phone assembly, but low-cost labour-intensive assembly remains economically advantageous. A 2015 study calculated that the processing cost per Samsung Electronics mobile phone in Viet Nam was equivalent to 30 per cent of the cost in the Republic of Korea (Lee and Jung 2015). It is estimated (*The Economist* 2018; Samsung 2018a) that the firm's factories in Viet Nam produced over 50 per cent of Samsung Electronics smartphones, and employed over 100 thousand people in 2017 – almost 60 per cent of all employees in Asia (excluding the Republic of Korea). And the company continues to invest in manufacturing capacity in emerging countries. In July 2018, Samsung Electronics opened the world's largest mobile phone factory in India (Samsung 2018b). At the same time, in 2016, the company announced investments of over US$2 billion in the United States, on the Internet of Things, R&D and a semiconductor factory to meet growing demand for chips (Samsung 2016a, 2016b). This indicates the preservation of the traditional international division of labour whereby high value-added technology-intensive activities (requiring less labour) remain in higher-cost locations while (more labour-intensive) assembly is done in low-cost locations.

3.4. Conclusion

New technologies and their potential impacts on employment feature prominently in public debates around the world today. Concerns over job losses stem from estimates based on the idea that jobs characterized by a high incidence of repetitive tasks are most susceptible to automation. In such context, employment in labour-intensive electronics assembly in middle-income countries is deemed at high risk of technological unemployment. Assembly workers would be in competition with automation in their own countries as well as in high-income economies, which could lead to reshoring. Fears are heightened by rising sales and stocks of robots in the electronics industry, especially in high-income countries. The existence of Samsung Electronics' highly automated mobile assembly plant in Gumi suggests that new technologies are increasingly capable of performing many of the assembly tasks traditionally done by hand, further corroborating the negative outlook on job displacement and reshoring. But this research indicates that there are several caveats to a scenario in which robots replace workers in fully automated assembly lines.

The majority of robots in the electronics industry are for the manufacture of components, rather than assembly, which have distinct technical needs and challenges. Moreover, despite advanced technical capabilities in the Republic of Korea, Samsung Electronics assembles over 90 per cent of mobile phones in labour-intensive low-cost locations. It thus appears that, currently, it does not make economic sense to adopt emerging automation technologies for electronics assembly and that the comparative advantage of low-cost labour persists. In addition, Foxconn's general manager for automation technology has stressed that for the foreseeable future, robots and workers will continue to collaborate on the shopfloor. This suggests that technological bottlenecks related to requirements such as flexibility and tactile dexterity have not yet been fully remedied. It is also possible that electronics assembly automation takes the shape of labour augmentation rather than displacement. It wouldn't be the first time that collaboration trumps displacement. It has been found that in the heavily automated automotive manufacturing, teams of robots and workers perform better than teams of workers or of robots alone (Gibbs 2016; Tobe 2016). Moreover, as demand for electronics rises and firms continue to invest in expanding capacity, even a small downward trend in capital-to-worker ratio in the industry could be offset by positive market expansion effects. It is worth noting that there is significant potential for growing demand. For instance, internet usage is growing rapidly in emerging economies, as is smartphone ownership, but many do not yet own mobile phones of any kind – about three in ten people in India and Indonesia, according to a recent survey by the Pew Research Center (2019), for instance.

Technology availability and growing consumer markets are not the only factors favouring the permanence of electronics assembly in middle-income countries. Previous research indicates that a significant movement of electronics manufacturing back to Europe and the United States is unlikely (Chang, Huynh and Rynhart 2016). Industry experts suggest that it would currently not be possible to achieve the same speed of production in Europe or the United States as is possible in China. Well-established Asian manufacturing hubs cluster suppliers, skills and infrastructure that may be hard and costly to replicate. Distance from the Asian supply chain has been cited as one of the factors threatening the promised LCD display factory in Wisconsin (Bauerlein 2019). The importance of clusters is also evident in months-long delays in the assembly of Apple computers in Texas due to the contractor's inability to procure sufficient US-made screws (Nicas 2019). In addition, a growing trend to keep production close to customers could eventually lead to some reshoring, but it could also support electronics production in emerging and developing countries with expanding markets. In Asia, rising labour costs in China provide opportunities to countries such as India and Viet Nam, with relatively low labour costs and sizable domestic markets.

It is also important to note that the impact of greater automation on workers is not restricted to job displacement but also affects working conditions and compensation. It has been argued that robots may improve workers' welfare by performing dirty, dull and dangerous tasks (Shea 2016). On the other hand, the presence of robots can increase pressure on the pace of workers, as has been observed in robot–worker collaboration in warehousing (Madhavan, Righetti and Smart 2018). Greater use of automation technologies in assembly lines could also reduce the number of workers or their working hours, with potentially negative consequences on wages. These are critical concerns in the assembly of electronics, where poor working conditions have made headlines on multiple occasions, including for issues related to under-compensation (Condliffe 2018). This is even more crucial given that many of the countries with large electronics assembly industries are not signatories to international conventions on freedom of association and collective bargaining.[33]

33 Such as the ILO Freedom of Association and Protection of the Right to Organise Convention, 1948 (No. 87) and No. 98, Right to Organise and Collective Bargaining Convention, 1949 (No. 98).

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4 Automation in Chinese retail warehouses

Xiao Jiang* and Ansel F. Schiavone**

4.1. Introduction

Rapid growth over the past few decades has significantly increased the purchasing power of Chinese consumers. By 2022, 75 per cent of Chinese living in urban areas are expected to be considered middle class (Barton, Chen and Jin 2013).[34] This explosive growth in purchasing power has led to the development of a thriving Chinese retail industry. With over 91,000 firms in 2015, the retail industry is a major employer of Chinese workers (Statista 2016). Hangzhou-based Alibaba, by many metrics the world's largest retail firm, employs over 50,000 workers, the majority of whom are Chinese (RT International 2016; Statista 2017). Many of these individuals work in warehouse logistics, which is responsible for packaging, shipping and storage of merchandise.

As online retail begins to dominate traditional department stores, the need for retail companies to optimize logistics operations has become a primary concern of the industry. Rather than depend on department stores to complete transactions, retail companies are primarily shipping goods directly to consumers. Because of this, operation costs for the retail industry have shifted from maintaining physical storefronts to warehousing and transportation. Growth of online purchases has thus led to rapid development of the warehouse industry, in an attempt to cut down on operational costs and improve profitability.

Warehousing is a location-dependent activity due to its need to rapidly deliver goods to consumers. For this reason, warehousing operations cannot be offshored (and

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34 "Middle class" defined as individuals earning US$9,000–$34,000 per year.

subsequently reshored) to the same degree as activities like manufacturing or customer service. Retail firms must look to reduce labour costs by other means. Automation has been the most prominent method of labour cost reduction, with highly publicized examples of robot-run warehouses that require little human labour. However, there are other methods that firms may use to cut labour costs. Nearshoring, particularly between domestic provinces, is likely to become a dominant trend in the Chinese warehousing industry. Significant variations in minimum wages between administrative regions in China provide opportunities for labour arbitrage without significant increases in distance from consumers. It is likely that firms will pursue both methods as the Chinese retail warehousing industry grows. While Chinese retailers have predominantly relied on labour-intensive warehouse models, made possible by low labour costs, there is evidence that firms are beginning to automate warehouses via robot technology, following in the footsteps of European and American retailers. This change could drastically reduce the number of warehouse jobs currently available to Chinese workers.

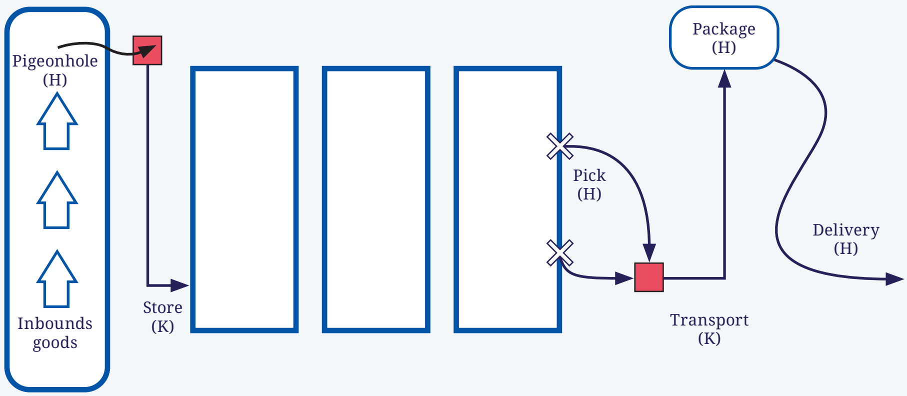
This case study will consist of five primary sections. Section 4.2 takes a detailed look at the necessary skills of warehouse employment, and discusses the technology that is currently used to automate warehouse processes. The section also provides brief examples of particular companies that are using robotics to automate warehousing operations. Section 4.3 provides a look at general trends of automation in China. Section 4.4 details the current state of Chinese retail warehouses, and analyses the potential effects of automation on workers currently employed in these warehouses, compared to the rest of the world. Section 4.5 briefly discusses the possibility of nearshoring. The final section provides concluding remarks and provides predictions for the future employment outlook of Chinese warehouse workers.

4.2. Understanding the technology

Warehouse work is a wide-ranging activity that involves many physical undertakings such as packing, sorting and stocking, as well as abstract tasks like inventory management and staff coordination. The mix of manual labour and logistical reasoning thus requires a highly robust skill set. Warehouse teams must be able to work together efficiently to meet deadlines, and be capable of distributing tasks amongst team members.

Technology capable of performing many of the manual aspects of warehouse tasks is relatively well developed. Hydraulic arms are capable of deftly lifting large packages; wheeled robots can transport items across the warehouse floor, and barcode scanners ensure that the correct packages are selected for delivery (Bhasin and Clark 2016). The larger challenge of automation arises when trying to coordinate fleets of heterogeneous robots to operate in synchronization. This task is further complicated by the variety of goods of different shapes and sizes that are stored by retail firms. A typical

▶ Figure 4.1. Amazon warehouse coordination between human workers (H) and Kiva robots (K)



retail warehouse will hold millions of different types of products at any given time (Bloomberg 2014). “Pick and place” robots, which are responsible for picking up and placing objects via robotic arms, must be robust enough to handle such variation in order for automation to be successful. Such technology is now sufficiently advanced and widely available, largely due to technological development driven by other industries (Wallen 2008). For example, Ocado, a UK-based grocery firm, has recently introduced two new robots designed to automate the task of bagging groceries. The technology utilizes 3D-vision technology, enabling the robot to analyse the contents of the bag at a given time and select an item of appropriate size and weight to add (Internet of Business 2017). Such technology can easily be applied to the packaging of retail items for shipment and delivery.

Retail giant Amazon has been a leader in development and implementation of robotics designed to automate warehouse operations. In 2012, Amazon purchased Kiva Robotics along with its primary product, termed simply the “Kiva robot”. The Kiva robot is a portable automated machine that is capable of transporting loads without any human direction. Despite the robot being less than one cubic meter in size, it is capable of carrying loads of over 1,300 kg (Steiner 2009). A fleet of Kiva robots operates via an entirely automated system. Within Amazon warehouses, Kiva robots are responsible for transporting large “shelves” of items to and from desired locations. Figure 4.1 provides a simplified depiction of the warehousing process with the implementation of Kiva robots. Inbound goods are pigeonholed into shelves wherever they will fit by workers, using digital scanners to track their location. Kiva robots then transport these loaded shelves to a designated storage location in the warehouse. As orders arrive, workers pick desired items from stored shelves and place them on an empty transportation cart. Once this cart is filled, it is transported again by a Kiva robot to the packing station. Packaging is done entirely by workers, but optimal package shapes are dictated by software. Finally, packages are addressed by an automated press and sent out for delivery.

As of 2015, Amazon was using Kiva robots in only 13 of its 123 warehouses, all of which were located in the United States or China. However, these automated warehouses were able to reduce operational costs per warehouse by approximately 20 per cent, a significant amount in an industry with relatively small profit margins. An added benefit of automation is increased warehouse capacity per square foot. While workers need wide aisles in order to pick items from storage shelves, the Kiva robot can fit in a gap that is only a fraction of the size required for a human. Thus, warehouse space can be more efficiently utilized when robots are responsible for retrieving items; Amazon warehouses that are outfitted with Kiva robots are capable of storing approximately 50 per cent more inventory per square foot than non-automated warehouses (Supply & Demand Chain Executive 2016). An average Amazon warehouse outfitted with an automated fleet has approximately five to ten Kiva robots per employee (Robotics Tomorrow 2011). The highly automated Kiva system has replaced the traditional labour-intensive method of workers manually retrieving items from shelves: "Amazon has long used automation in its fulfillment centers, and Kiva's technology is another way to improve productivity by bringing the products directly to employees to pick, pack and stow" (Amazon 2012).

The integration of Kiva robots into the Amazon warehouse system is transforming the role of warehouse employees. Rather than the physically demanding work that was previously ubiquitous in the job, Amazon workers in automated warehouses are now more occupied by technical tasks such as maintenance and troubleshooting. Employees that would have spent their day walking miles to retrieve products now occupy a more stationary role involving "pick and place" tasks, which are also aided by the use of hydraulic arms and other robotic picking devices (Wingfield 2017).

Chinese robotics company Hikvision is currently in production of a robot similar to Amazon's Kiva. The major Chinese delivery company, STO Express, has already implemented Hikvision's robots into their business model. In the STO warehouse, a fleet of 300 robots is able to sort 200,000 parcels a day. The robots are able to enter and exit the sorting process autonomously in order to charge, eliminating the need for any regular system maintenance by humans (You 2017): "Hikivision smart robot system is designed to catch the trend of 'machine substitution' for manual labor ... Hikvision introduces smart robots as the substitution of human labor for unmanned operation in accepting, sorting, and handling of goods" (Hangzou Hikrobotics 2018).

Chinese retail giant Alibaba is currently in the process of implementing Kiva-like robots in warehouses of their own. The robots, built by Chinese company Quicktron, have approximately doubled the quantity of packages capable of being processed by the same number of employees. Alibaba is still in the early stages of automation, and only a select few warehouses have been outfitted with robotic fleets (Guide in China 2017). However, it has been heavily involved in the funding of robotic development, as is discussed in the following section.

The greatest technological bottleneck of warehouse automation is the challenge of integrating multiple automated systems. For example, both the Amazon and STO Express systems require workers to manually pick up and scan items before transferring them to a conveyer belt. This challenge arises due to the variety of different shapes and sizes of packages; while a human hand can easily adjust to grip objects of different shapes, robotic "hands" do not have the same level of dexterity. Engineers are currently working on overcoming this issue through methods of "deep learning",[35] where robots adapt and improve performance based on past experience (Markoff 2015).

An institutional bottleneck that has significantly slowed the implementation of robotic warehouse systems by other retail firms is the tendency for large retailers to acquire robotics companies, effectively removing their technology from the market. In other words, there are market barriers created by large retail firms. Similar to the way Amazon purchased Kiva Robotics, Google acquired the robotics company Industrial Perception, halting all sales to competing retailers (Tobe 2016).

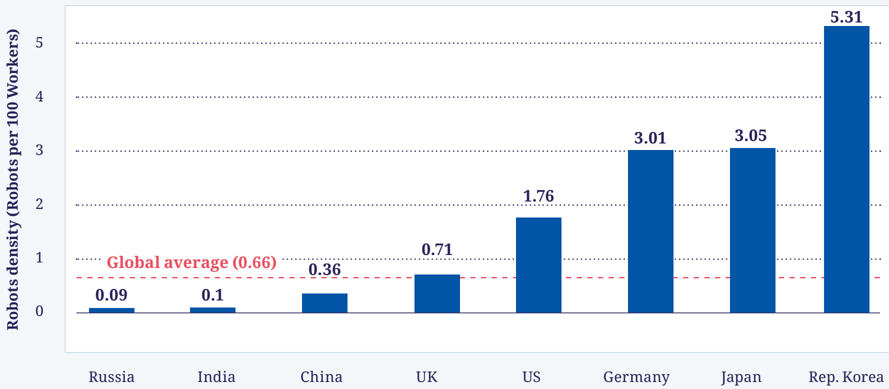
While major retail firms restrict the sale of robots in an attempt to preserve their technological advantage, other companies have begun to develop similar robotic systems to sell to competing retailers. The void left by the removal of Kiva robots and others from the market has led to competition amongst numerous start-ups and established robotics companies. As these firms compete to service the growing demand for warehouse robots, they continue to add capabilities such as packaging, restocking shelves, and unloading delivery trucks (Tobe 2016). These developments have the potential to further reduce warehouse reliance on human labour.

4.3. General trends of Chinese automation

Recent initiatives by the Chinese Government have led to significant growth in the development and implementation of robots within the economy. The government programme titled "Made in China 2025" aims to increase robot density (defined as the number of robots per 100 workers) to 1.5, up from its 2015 level of 0.36 (IFR 2016a, 2017). China currently lags behind the global average density of 0.66 (see figure 4.2).

35 Deep learning is a particular type of artificial intelligence that utilizes computational data structures designed to simulate biological "neural networks". This structure allows programs to adapt through experience while in use, much like the human brain. Deep learning has the potential to greatly enhance machine intelligence, allowing machines to "learn" as opposed to simply being programmed.

▶ **Figure 4.2. Robot density, by country**



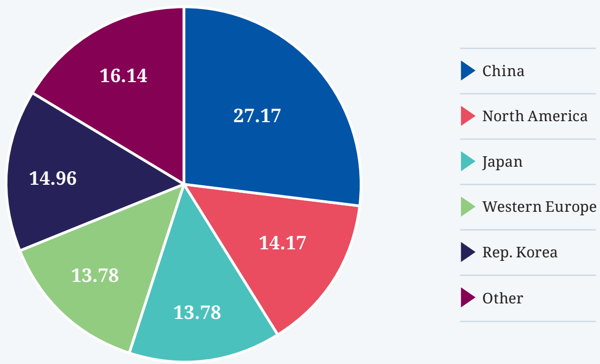
▶ Source: IFR 2016a.

China's level of robot density is significantly lower than neighbouring Japan and the Republic of Korea, as well as Germany and the United States. The Chinese Government plans to achieve this goal of increased automation by loosening restrictions on foreign investment, as well publicly funding private ventures aimed at increasing automated processes.

In order for China to achieve its goal of 1.5 robot density by 2025, the country will have to add over 600,000 industrial robots (IFR 2016a). There is strong evidence that China is well on its way to achieving this goal. In 2015, China purchased or produced 69,000 industrial robots, consuming over 27 per cent of global supply (IFR 2016b) (see figure 4.2). This rate of industrial robotic accumulation far surpasses that of any other country.

It is clear that major technological changes are under way within the Chinese economy. The country is striving to achieve a level of automation similar to that of developed nations in Asia, North America and Europe. However, despite lagging behind in robotic automation, China is currently the world's largest merchandise exporter, relying heavily on labour inputs to maintain its high level of productivity. The impending wave of automation has the potential to greatly reduce the need for workers in the Chinese economy, which could be highly problematic for the world's most populous nation.

Figure 4.3. Consumption of global industrial robot supply



Source: IFR 2016a.

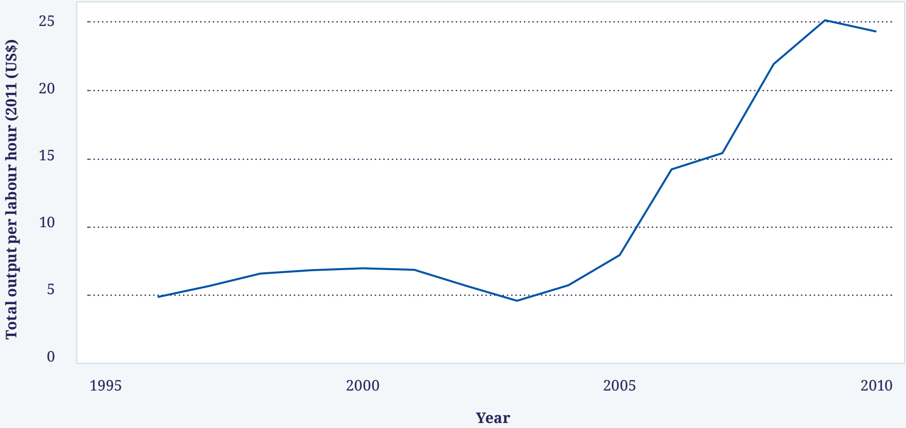
4.4. Automation in Chinese retail warehouses

There have been recent highly publicized examples of Chinese firms automating warehouse operations, replacing significant numbers of employees with robots. As mentioned previously, the delivery company STO Express automated its warehouse sorting process using Hikvision robots. With a fleet of 300 robots, the company has been able to reduce labour needs by 70 per cent (You 2017).

Alibaba has also been experimenting with automation, and appears to be following the model set by Amazon and Google in an attempt to acquire a warehouse robot of its own. The company plans to invest US$15 billion in research and development over the next five years (Chen and Dai 2017). Alibaba has invested in several robotics companies, including Quicktron and Geek+, both of which produce robots similar to that of Kiva (Millward 2017). Once the technology is developed sufficiently, it is likely that Alibaba will attempt to purchase proprietary rights to preserve its technological advantage, as Amazon did with Kiva. Given that Alibaba currently employs nearly 50,000 Chinese workers, an employment displacement effect similar to that observed in STO Express's robotic warehouse would eliminate a significant number of jobs.

While these empirical examples are often touted as signs of an impending technological revolution, it is important to realize that the process of automation in Chinese warehouses is already under way. Data from the World Input-Output Database details

Figure 4.4. Labour productivity in the Chinese auxiliary transportation sector



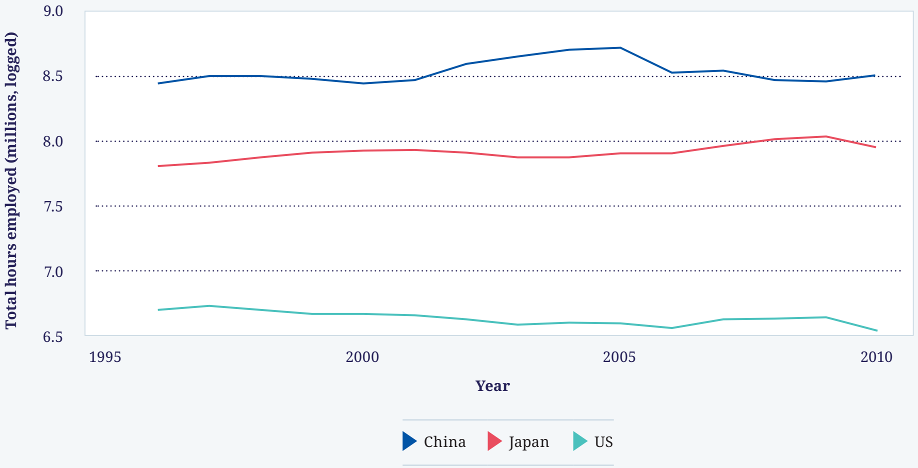
Source: UNIDO, 2017

transformations in the “auxiliary transport activities” sector, which includes warehouses (IBIS World 2017).[36] Labour productivity in the sector has increased drastically in the past two decades (see figure 4.4), which can be explained in large part by the incorporation of new technologies into the production process.

Despite the dramatic increase in labour productivity, total labour inputs in the Chinese sector have not decreased. Rather, total sector output has increased in response to higher labour productivity. Employment in the sector spiked in 2003–05, and then returned to a level similar to earlier years (see figure 4.5). This spike in employment corresponds roughly to the beginning of explosive sectoral output growth (see figure 4.6). The drastic increase in employment followed by a return to previous levels suggests that warehouses increased labour inputs in the short run to meet heightened demand, but in the long run began to incorporate technologies to increase labour

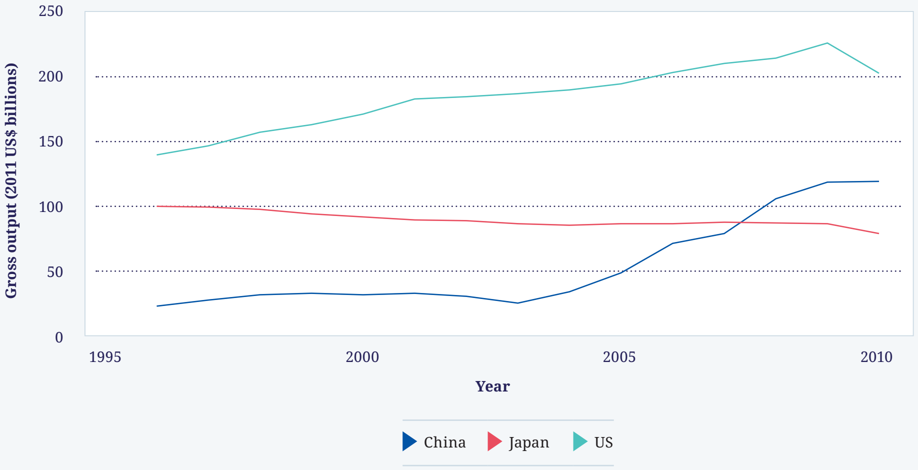
36 Data on the warehousing industry alone is not available for extended periods of time. However, “auxiliary transport activities” include warehousing, and therefore serves as a proxy for the warehousing industry. Warehousing activities make up approximately 35 per cent of all auxiliary transport activities (IBIS World 2017). This composition is observed to be relatively stable over time, thus justifying the use of auxiliary transport activities as a proxy. Furthermore, the other activities accounted for in the auxiliary transport industry are highly linked to warehousing (cargo handling, storage and transportation), suggesting that changes in productivity, output or employment in any particular industry subclass would likely be accompanied by similar changes in other supporting and auxiliary activities.

▶ Figure 4.5. Labour inputs in the auxiliary transportation sector, by country



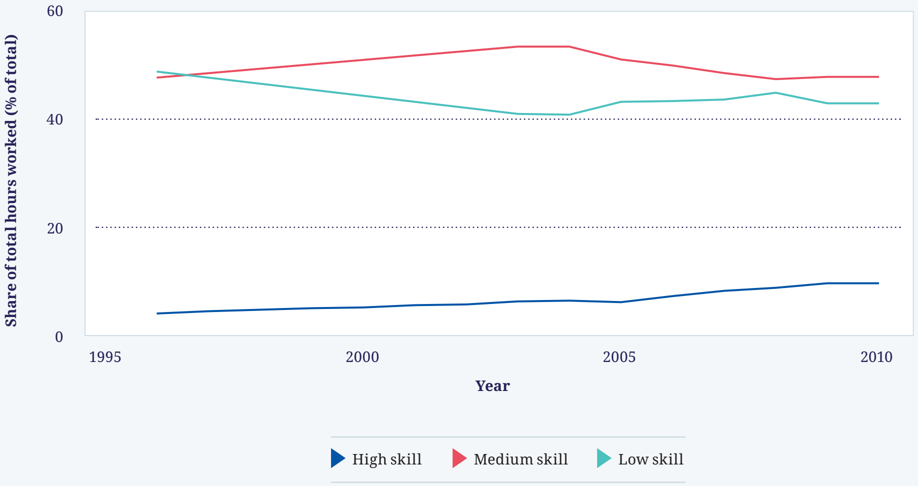
▶ Source: WIOD 2014.

▶ Figure 4.6. Gross output of the auxiliary transportation sector, by country



▶ Source: WIOD 2014.

Figure 4.7. Skill composition of the Chinese auxiliary transportation sector



Source: WIOD 2014.

productivity and reduce labour inputs. The increase in labour inputs appears to be isolated to the Chinese sector, as Japan and the United States experienced no similar spikes. Furthermore, the Japanese and American sectors did not exhibit the corresponding rapid increase in output or productivity experienced by China.

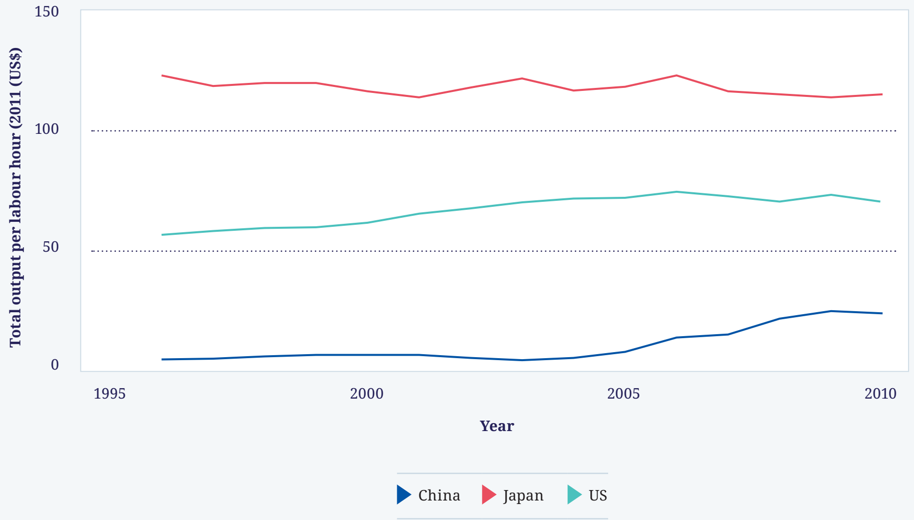
Such changes in labour productivity have transformed the skill composition of the sector's labour force. The percentage of highly skilled workers has steadily increased for more than a decade (see figure 4.7). The years of 1997–2004 saw an increase in the percentage of medium-skilled workers, accompanied by a fall in the percentage of low-skilled workers. However, from 2005 to the present, this trend has been somewhat reversed; the percentage of low-skilled workers has risen, at the apparent expense of medium-skilled workers. The beginning of this trend reversal coincides roughly with the dramatic rise of labour productivity and output (see figures 4.4 and 4.6). These changes in the skill composition of the sector's labour force seem to imply a tendency towards job polarization in warehouse employment. The need for highly skilled workers such as computer technicians, mechanics and engineers necessarily increases with automation. At the same time, highly automated systems increase division of labour within warehouse operations, reducing the need for workers on the floor to have knowledge of optimizing strategies or inventory management. Rather, workers are simply responsible for single tasks that require less skill, thus explaining the decrease in medium-skill employment (Chew 2017).

Labour costs were likely to have been the primary reason Chinese warehouses chose to implement labour-saving technology after the dramatic increase of labour inputs in 2003–05. Average real wages in China have increased more than six-fold in the past four decades (Trading Economics 2017; Yang, Chen and Monarch 2010). However, wage growth has been uneven both regionally and in terms of worker skill-level; it has been highest in eastern provinces, particularly in and around major cities such as Shanghai and Beijing, while slower growth is observed in the more rural western provinces. High-skill industries such as information and banking have seen dramatic increase in wages, outstripping that of low-skill activities such as manufacturing and wholesale and retail trade. Nevertheless, even low-skilled workers have seen their real wages rise more than three-fold in merely 20 years (Yang, Chen and Monarch 2010). There is a lack of consensus as to the cause of the rise in unskilled wages. However, there is some evidence to suggest that surplus urban labour has been depleted due to the combined effect of economic expansion and government policies such as single-child legislation and guest worker restrictions. Such institutional arrangements limit the supply of labour to urban areas: the former by reduced birth rates and the latter by restricting migrant workers' access to social security programmes (Golley and Meng 2011). These policies have reduced the supply of cheap labour both from younger generations and rural migrants, thereby raising worker wages. This rapid rise in low-skilled wages has inevitably increased labour costs for warehouses, increasing firms' incentives to automate.

It is important to note, however, that despite increases in labour productivity, gross labour inputs have remained at approximately the same level as in the pre-automation era. It appears that the rapid growth of the Chinese economy, especially in consumer-based industries such as retail, has generated significant demand for the services of the auxiliary transport sector. China's expanding middle class, combined with the development of e-commerce, is responsible for this extensive industry expansion. Analysts also cite low car penetration levels and traffic congestion as reasons why Chinese consumers prefer ordering goods online rather than visiting retail locations (Asian Robotic Review 2016). This explosive growth in demand explains why the sector requires a similar amount of labour inputs as a decade before, despite a nearly five-fold increase in labour productivity.

Notwithstanding individual examples of warehouses replacing large portions of their labour force with robots, it seems as though market expansion dynamics have effectively countered labour displacement thus far. This is not to say that Chinese warehouse workers have not experienced unemployment due to automation; the highly skilled workers currently enjoying greater shares of total labour hours in the sector are not likely to be the same low- and medium-skilled workers who have seen their labour

▶ **Figure 4.8. Labour productivity of auxiliary transportation sectors, by country**

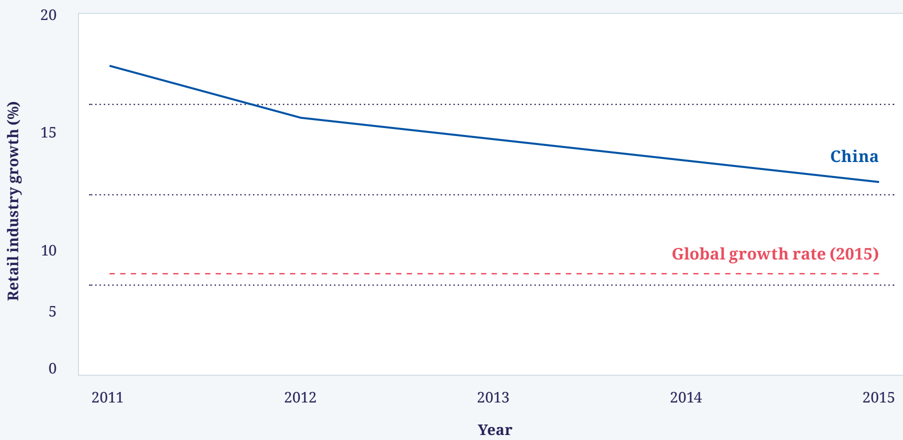


Source: WIOD 2014

shares decline. However, market expansion has nonetheless created approximately as many employment opportunities as have been destroyed due to automation. The question remains as to whether this pattern will continue in the future.

Despite dramatic increases in recent years, labour productivity in the Chinese auxiliary transportation sector is still significantly lower than those of other developed nations (see figure 4.8). In 2014, the sector employed more than three million workers, approximately twice as much labour as that of the United States, and eight times that of Japan (WIOD 2014). As China's economic growth slows, industries employing warehouse services, such as retail, appear to be converging towards lower rates of growth (see figure 4.9). Thus, it appears as though market expansion will begin to slow in the coming decades. This does not imply that the process of automation will act accordingly. As the Chinese Government pursues policies of market liberalization and decreased restrictions on foreign investment, Chinese warehouses will be likely to continue to adopt labour-saving technology already in use in many other developed countries. Such a combination of slowed growth and continued automation may very well lead to decreased warehouse employment, particularly for low- and medium-skilled workers.

Figure 4.9. Chinese retail market growth



Source: WIOD 2014

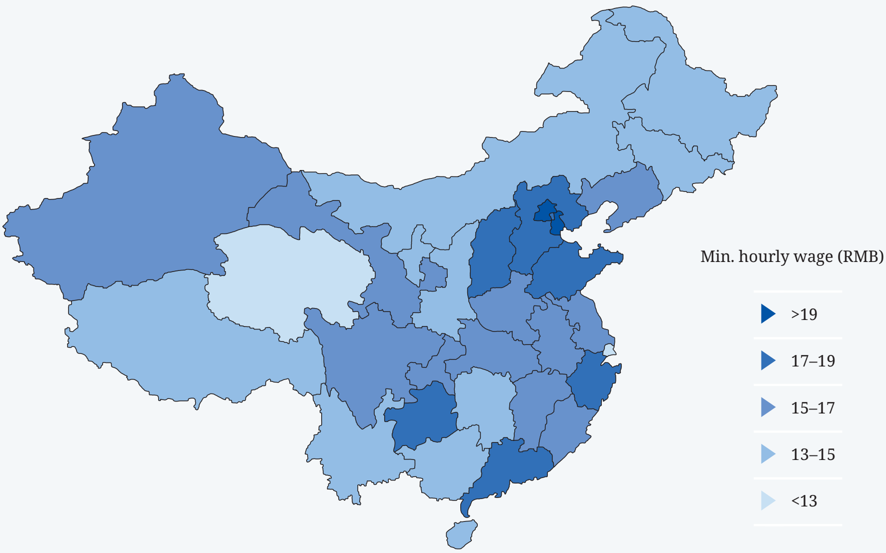
4.5. Nearshoring

Along with automation, the process of nearshoring is a potential way in which Chinese retail warehouses may try to reduce labour and other input costs. Nearshoring has already been observed in the Chinese manufacturing sector. With the rapid rise in Chinese wages, a significant amount of manufacturing wages have moved to other countries in South-East Asia, or even back to North America. This trend of nearshoring (or reshoring in the case of movement back the United States) has led to debates as to whether a slowdown in Chinese manufacturing is imminent, although there is a general lack of consensus on this question in the literature (Simchi-Levi 2015).

Unlike manufacturing, however, warehousing activities are location-dependent. Increased distance from final consumers raises transportation costs and can delay delivery expedience – a vital characteristic of online retail. Thus, moving warehousing operations to different countries is much less advantageous. However, there is significant wage variation within China, which opens the possibility of domestic nearshoring (see figure 4.10).

Unsurprisingly, the three largest population centres in China – Chongqing, Shanghai and Beijing, respectively – have some of the highest minimum wages in the country (Wage Indicator 2018). Since these cities represent a significant portion of online

Figure 4.10. Chinese minimum wage, by province, 2016



Source: *Wage Indicator* 2018.

retail demand, establishing warehouses close to these urban centres is highly desirable. Thus, neighbouring provinces with lower wage levels are ideal locations for retail companies to establish supply networks, taking advantage of both proximity to consumers and relatively lower labour costs (Chen and Hamori 2009; Knight, Deng and Li 2011; Golley and Meng 2011).[37] For example, the minimum wage in Jiaxing in Zhejiang province is only 65 per cent of that in neighbouring Shanghai, despite a distance of only 100 kilometres. Similarly, the province of Hebei, which borders the municipalities of Beijing and Tianjin, has a minimum wage only 80 per cent of that of the capital (*Wage Indicator* 2018).

Certain Chinese provinces such as Yunnan and Guangxi border the Greater Mekong countries of Laos, Myanmar and Viet Nam, all of which have labour costs below that

37 China is unique in its historical reliance on migrant workers to fill labour shortages. Migrant workers are often disadvantaged due to their precarious position in the labour market. While significant populations of rural workers still exist, there is a growing consensus in the literature (Chen and Hamori 2009; Knight, Deng and Li 2011; Golley and Meng 2011) that migrant workers are increasingly removed from urban workforces, either by choice or through institutional and political pressures. For this reason, we believe that provincial minimum wage is a legitimate, albeit imperfect measure for the cost of low-skilled labour.

of China. It seems possible that international nearshoring could be implemented in these border provinces. Empirically, however, this does not seem to be the case. According to WIOD 2014 input-output data, total expenditure on auxiliary transportation services by Chinese households, firms, and government was US$2.27 billion. A full 98.5 per cent of these expenditures came from within China, with only US$52 million (less than two-tenths of one per cent of total Chinese auxiliary transportation expenditures) coming from the rest of East Asia. Compared to more tradable industries such as rubber and plastic manufacturing (81 per cent domestic expenditure; 9.5 per cent in East Asia) or chemical products (52 per cent domestic expenditures; 13.6 per cent in East Asia), auxiliary transportation expenditures in China seem highly domestically concentrated. While trade policies may partially explain such discrepancies in expenditures, it seems plausible that the proximity requirement of warehousing and greater auxiliary transportation activities necessitate domestic operation.

Thus, while international nearshoring may not be feasible for retail warehousing in China, domestic labour arbitrage is a legitimate way in which online retailers can reduce warehouse labour costs while still preserving advantageous proximity to final consumers. As rising wages continue to pressure Chinese retailers to find ways of cutting labour expenses, it is likely that the relocation of warehouse operations will accompany the trend of automation.

4.6. Conclusion

As the Chinese population continues to enjoy higher purchasing power, retail firms will be forced to fill the increasing demand for consumer goods. Incentivized by rising labour costs and government initiatives, it is inevitable that Chinese firms will seek to automate their warehouses. Early examples have shown robotic automation to be extremely effective at cutting labour costs and reducing warehouse employment, while increasing storage capacity.

The empirical example of 70 per cent labour displacement, however, should be taken as an improbable worst-case scenario. While completely automated warehouses may eventually be the reality worldwide, it is important to recognize that such technological endeavours represent enormous, risk-filled investments for Chinese retailers. Warehouses will continue to automate in response to rising labour costs, but likely at a gradual rate.

With higher labour productivity, retail firms will continue to expand operations to meet the increasing demand generated by a growing Chinese middle class. This expansion will most likely occur in regions with close proximity to large urban centres with relatively low wages. This market expansion will be accompanied by a continued transformation of warehouse labour composition, with highly skilled workers replacing those of low and medium skill. However, as growth in the Chinese retail market slows and wages continue to increase, firms will be forced to implement labour-saving technology into their business models. Fortunately for warehouse employees, this scenario is not in the near future. Growth in the Chinese retail industry is still nearly double that of the global average, and demand for retail products among Chinese consumers shows no signs of slowing (Deloitte 2016; Barton, Chen and Jin 2013).

China is undoubtedly the location of the next major wave of automation. However, the threat of large-scale worker displacement in warehouses appears at worst to be in the relatively distant future. Despite a slowdown in recent years, the continued growth of Chinese purchasing power seems to imply that market expansion and industrial upgrading will be the focus of retail firms, not strictly labour substitution. The more immediate threat to Chinese warehouse workers is unemployment due to inadequate skill sets rather than automation-led job destruction.

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5 Call centres in India and the Philippines

Xiao Jiang and Ansel F. Schiavone

5.1. Introduction

The global outsourcing industry generated US$76.9 billion in 2016, with business process outsourcing (BPO) – the supply of business-related services – responsible for over 30 per cent of the revenue (Statista 2017). Call centres make up a large portion of the BPO industry. Approximately 70 per cent of those employed in the industry in India and the Philippines work in call centres, 350,000 and 400,000 individuals respectively (Magellan Solutions 2016). These businesses handle customer services outsourced by companies from around the world. Employment at these centres requires little skill besides language proficiency – generally in English. However, the relatively recent development of vocal recognition technology has allowed some companies to shift from BPO to automated "humanoid" call attendants. This form of robotic process automation poses a direct threat to these call centres.

The Indian and Filipino call centre industries serve as interesting case studies for several reasons. The historical trend has been for firms from developed countries – particularly those in which English is the primary language – to outsource customer services to developing countries with low labour costs and large English-speaking populations. The Philippines and India have the largest and second largest call centre industries in the world respectively, and provide nearly identical services to firms looking to outsource customer support (Winn 2014). Because of this, both industries face similar threats of automation from rapidly improving technologies.

These technical changes are likely to have an impact on employment in the two countries. Given that both industries service firms from developed nations, there is a high likelihood that improved automated capabilities will significantly weaken the comparative advantage of cheap labour that is currently enjoyed by Indian and Filipino call centres. This could lead to a process of relocation of operations to countries of the customers being served, given that it is no longer cost-effective for firms to transfer these services offshore. Unlike final goods-producing activities such as manufacturing, this process could be further accelerated by consumers' preferences for domestic customer service support. Thus, reshoring of call centres is driven both by technical change and consumer preferences. For this reason, the call centre industries of India and the Philippines allow an excellent look at how automation can quickly transform industry dynamics in the era of modern globalization.

This case study aims to provide a general overview of the Filipino and Indian call centre industries, analysing the potential for automation within each nation, and the subsequent effects on those employed as call centre workers. The study consists of seven sections following this introduction; section 5.2 provides a brief overview of the technology used in the call centre industry and discusses its potential for increased automation. Sections 5.3 and 5.4 provide brief overviews of major players in the IVR development and call centre industries respectively. Section 5.5 takes a detailed look at the Indian and Filipino call centre industries, analysing a variety of different metrics to garner an understanding of the current level of automation within the two countries' industries, as well as the potential for future automation. The section then discusses the potential impacts on Indian and Filipino call centre employees. Section 5.6 examines the possibility of complete automation of the call centre industry due to advances in artificial intelligence. Section 5.7 discusses the possibility of call centre industry reshoring, while the final section provides concluding remarks and highlights areas where additional research is necessary.

5.2. Understanding the technology

The Institute for Robotic Process Automation and Artificial Intelligence defines robotic process automation (RPA) as "the application of technology that allows employees in a company to configure computer software or a 'robot' to capture and interpret existing applications for processing a transaction, manipulating data, triggering responses and communicating with other digital systems" (IRPAAI 2014). Automated attendants – software that is capable of completing some or all of the tasks traditionally performed by a human employee, thus fall under this general classification of RPA. Automated attendants have been around for several decades. Earlier forms presented callers with a generic menu option, such as: "press 1 for sales, 2 for customer support". While this "early" automation reduces the need for a phone receptionist, it simply routes callers to whomever they are trying to contact, thereby eliminating only the labour of the receptionist. Furthermore, this more rudimentary system requires the integration of phone keyboards for option selection, making the process more cumbersome for the user.

Modern forms of automated attendants, however, incorporate technology of interactive voice response (IVR). IVR utilizes voice recognition software to allow computers to interpret human speech, allowing users to communicate with the system as one would with other humans. The International Federation of Robotics does not classify IVR technology as robotic, as robots are defined as an "actuated mechanism programmable in two or more axes" (IFR 2018). However, the artificial intelligence algorithms used in next-generation IVR are extremely similar to those of advanced robotics. Rudimentary forms of IVR use a combination of vocal recognition algorithms and traditional key-selected menu options (Tolentino 2015). More advanced IVR systems are increasingly relying on artificial intelligence to enable users to rely exclusively on voice interaction. For example, automated speech recognition technology used in many advanced IVR systems interprets user input by analysing each decipherable word, and then selects what it predicts to be the desired option of the user based on a statistical prior. Once in use the system can improve its performance by adjusting this prior based on user feedback (Wathne 2017). In this way, artificial intelligence and machine learning are allowing IVR systems to understand and correctly respond to increasingly complex user input.

Text-based attendant automation, known as “chatbots”, work in a similar manner to advanced IVR systems. Rather than interact with users on the phone, chatbots can exchange SMS messages to answer questions and handle customer enquiries. As with machine-learning IVR systems, advanced chatbot systems utilize statistical priors to improve performance once in use (Reddy 2017).

IVR and chatbots are extremely effective in automating call services such as customer assistance and sales. By replacing the 1-to-1 caller-employee relationship with a 1-to-n relationship, where n is the number of callers serviced by a particular system at a given time, these technologies reduce the amount of human-to-human interaction, particularly in areas where relatively simple tasks are being performed. IBM estimates that automated attendants save call centre firms approximately US$0.70 for every interaction with a customer (Wathne 2017). Whether the system is able to handle the entire call automatically, or rather collects basic information before transferring the caller to a human agent, such technology increases efficiency significantly. This reduction in the human labour required to service a customer may thus negatively impact employment, either by number of individuals employed or hours worked. However, there is also the possibility that the increased productivity of such systems will allow call centre employees to focus on more complex tasks, and even increase the services provided by call centres. These possibilities will be discussed in the following sections.

While the potential for automation is great, there are, however, certain tasks that IVR cannot fully perform. IVR is extremely effective in automating simple operations such as accessing itinerary and account information, handling user input, and presenting menu options. More complex tasks, however, such as sales and customer service, cannot be performed by IVR technology alone; these highly abstract tasks require the labour of human employees.

The following section takes a look at some key players in IVR development, highlighting the ways in which these firms continue to improve IVR technology, while addressing its shortcomings through integration of multiple forms of media.

5.3. IVR development: Major players

The market for automated attendants is expanding rapidly, and several firms have emerged as leading suppliers of these technologies, such as [24]7 Inc., an American company founded in 2000. The company provides IVR systems integrated with SMS messaging, allowing customers to service their needs using both voice and text interactions ([24]7.ai 2018).The goal of this integration is to overcome certain technical shortcomings of IVR, such as the need for consumers to supply complex and/or proprietary information over the phone:

> In today's digital world, consumers expect an interactive experience across all channels–including the IVR. Unfortunately, most often the IVR experience is not interactive. In addition, those who are on the web and on the phone simultaneously have to track two fragmented interactions. This results in a disjointed experience requiring higher customer effort, especially since voice interactions and web content typically are not designed to work well together. ([24]7.ai 2017)

The ability to integrate multiple forms of digital media with telephone communication is highly important in an age where the internet is the dominant method in which consumers process information. The primary goal of [24]7 has therefore been to develop a system in which IVR acts as a complementary channel of communication with consumers:

> One common scenario today is a consumer who would first go to the web to change their address on their account. However, if the customer can't find where to make the address change, they would most likely call to speak to an agent to help assist them. Once they call in and reach the IVR, using presence, the IVR is aware that the caller was recently on the web and knows precisely what they were doing. ([24]7.ai. 2017)

Avaya is another American company that specializes in selling technology directly to call centre companies. Avaya's Self-Service Optimization is a software platform that utilizes IVR technology as well as traditional menu selection to "help customers quickly answer questions and resolve issues while minimizing the number of human resources needed" (Avaya 2012). The IVR platform utilizes phonetic speech technology, which indexes spoken words based on their pronunciation rather than part of speech (Black 2014). This allows the software to correct for ambiguities in the spoken input of users, similar to a spell checker:

> Using phonetic search [allows] you to capture calls regardless of the source, then use advanced analytical tools to mine the phonetic records from those calls to identify specific topics, people and calls. This approach is highly efficient, offering dramatically reduced latency and far more scalability than speech-to-text technology. (Avaya 2012)

With tech companies supplying a wide variety of automated attendants to the market, it is up to companies in the call centre industry to determine the most effective technology to incorporate into their business models. While these call centres clearly have interests in reducing labour costs, there are particular drawbacks to automation, particularly when considering the preferences of call centre clients.

5.4. Call centres: Major players

Teleperformance is a multinational corporation that specializes in business process outsourcing. The company reported annual revenue of US$4.05 billion in 2017. Teleperformance employs 217,000 individuals in more than 300 call centres worldwide. The company has approximately 4,600 employees in India and 45,000 in the Philippines (Singh 2016). Services offered by Teleperformance encompass a range of business processing services, including sales and customer support. Teleperformance advertises the ability to reduce companies' servicing costs by up to 60 per cent. While the company relies heavily on offshoring and labour arbitrage to provide competitive prices, it has also incorporated IVR and chatbot automation into its services: "We can create programs that meet the specific goals according to the values of different customer segments through the implementation of … integrated IVR/live-agent solutions" (Teleperformance, 2017a).

Teleperformance has a partnership with previously discussed IVR developer Avaya. The two companies have now worked together for many years. In 2013, Teleperformance purchased Avaya SBCE, a Sessions Initiated Protocol (SIP) network, to allow for the integration of multimedia into the services provided by call centre agents. This system allows agents to receive customer information entered via the internet, eliminating the cumbersome task of receiving such information over the phone. As Richard Blake, Teleperformance manager, comments: "We can reduce our hardware expenses, simplify implementations, and use fewer resources, saving us time and money. Avaya SBCE is critical in helping protect our network, while delivering the cost-saving benefits of SIP" (quoted in Market Wired 2013).

In response to increased preference of consumers for chat interactions, Teleperformance has been actively pursuing implementation of chatbots to complement its call centre employees. Chat is now the third-most preferred form of communication for customers seeking support, and demand is highest among young consumers (Teleperformance 2017b). In 2017 Teleperformance launched a chatbot platform capable of communicating with customers in 35 languages, with the intention of complementing customer–agent interactions: "Teleperformance has developed a distinctive capability of blending chat bots with live support to make the process of addressing customer inquiries seamless, personalized and efficient" (Business Wire 2017)

Genpact is another multinational provider of business services. The company employs approximately 78,000 individuals worldwide, with more than 20,000 located in India (Rediff 2006). Like Teleperformance, Genpact has adopted IVR technologies into its business model (Genpact 2017). However, Genpact also stresses the limitations of these technologies, citing primarily consumer preferences for human-based interactions: “Rather than simply focus on speed and volume, companies should aim to resolve customer concerns on the first call, which could increase their chances of cross selling or upselling additional services to these customers” (Genpact 2013).

Genpact’s concern regarding customer preferences is generally understood as a leading problem for the complete incorporation of IVR technology in the call centre industry. This will be discussed in greater detail in the following sections.

With the two largest call centres industries in the world, India and the Philippines provide interesting cases at how leading call centre companies are adapting to the growing capabilities of IVR technology, and how these changes will have an impact on employment in their respective national industries. The following section takes a look at industry-level trends in these two countries.

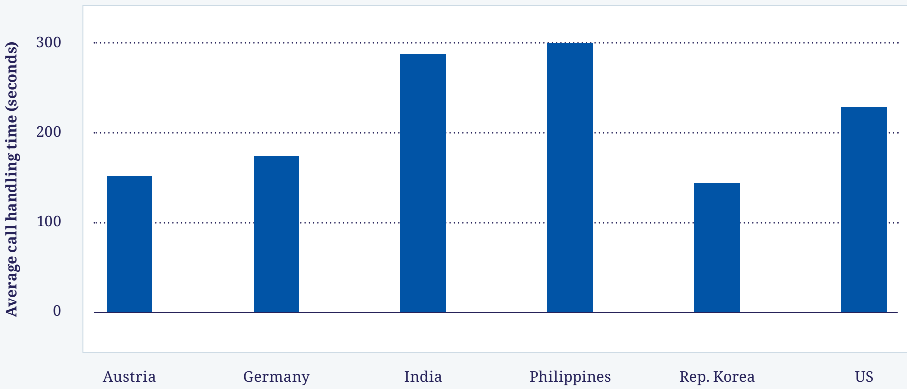
5.5. Indian and Filipino call centre industries

The call centre industry in India employs approximately 350,000 workers, making up approximately 10 per cent of the nation’s overall BPO industry (White 2015). In recent years growth of the Indian call centre industry has stalled, raising questions as to whether call centres will continue to serve as major employers in the BPO industry. Automation has the potential to further damage call centre employment, depending on the speed at which it is incorporated into Indian BPO business models.

A primary reason for the stagnation of call centre growth in India is increased competition by countries such as the Philippines. With 400,000 workers, the Philippines has now surpassed India as having the largest number of citizens employed in call centres (White 2015). Market analysts generally attribute the preference for Filipino-based call centres to cultural similarities between Filipino agents and their primarily American customer base (Magellan Solutions 2016). While Indians are taught British English, Filipinos learn American English, making phone communication easier for Americans due to their neutral accent (The Economist 2016). However, despite these cultural variations, the call centre industries in India and the Philippines are quite similar, and thus face comparable threats of automation in the near future.

An important metric when analysing the potential for call centre automation is the average call handling time per agent. Handling time is defined as the number of seconds a call centre employee is on the phone with a customer. Indian and Filipino call centres both have average handling times of approximately 300 seconds (Holman, Batt and Holtgrewe 2007; Magellan solutions 2016). This indicates that for a call centre agent to service one customer takes on average five minutes. Compared to averages in Austria (153 seconds), Germany (175 seconds), Republic of Korea (145 seconds) and

Figure 5.1. Average call handling time, by country



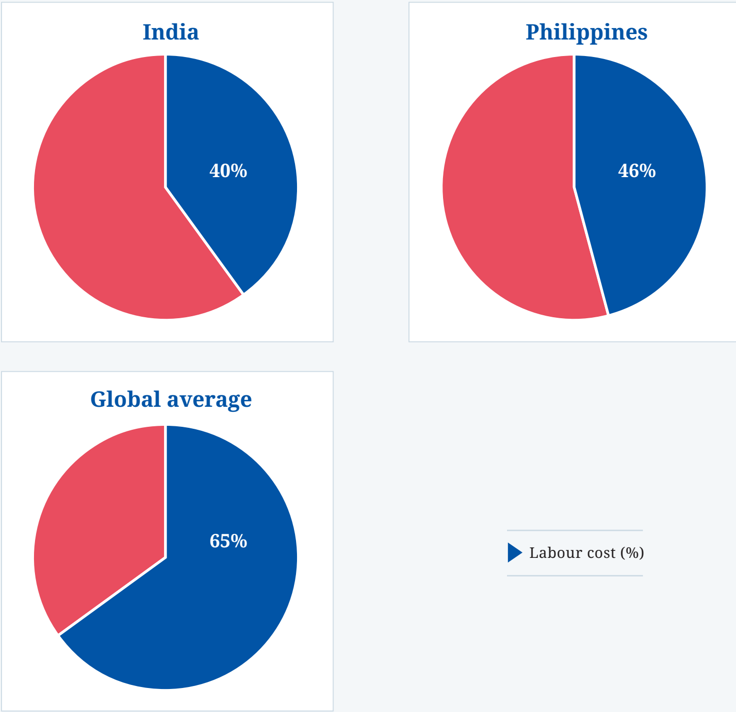
Source: Magellan Solutions 2015a.

the United States (230 seconds), Indian and Filipino agents spend significantly more labour time per customer (see figure 5.1).

IVR technology allows for customers to provide information and select services before talking to human agents. These tasks, which otherwise require customer–agent interaction, are completed via customer interaction with a computer, thus reducing handling time. It is difficult to measure the current degree of call centre automation in a particular country, but handling time may provide some insight as to the potential for future automation. While handling time may serve as a proxy for the level of IVR in use in a particular country, it is quite possible that the services provided by Indian and Filipino call centres are simply more time-intensive than those of developed countries. Nevertheless, the primary issue in question is whether there is potential for automation in the Indian and Filipino industries. Thus, even if these industries are handling more complex tasks, the continual development of IVR and chatbot technologies should eventually allow for reductions in handling time. If this is the case, automation has the potential to significantly reduce average handling times, which would in turn reduce the demand for call centre employment in these two countries.

Despite potential automation, Indian and Filipino call centres may not necessarily experience large-scale employment loss due to the incorporation of IVR technology. The greatest difference between Indian and Filipino versus US call centres is still access

Figure 5.2. Labour cost as a percentage of total cost

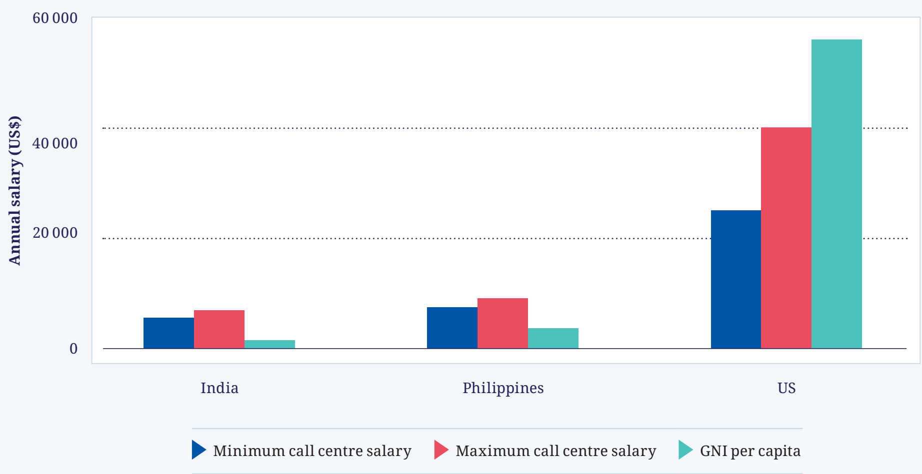


Source: Magellan Solutions 2015a.

to domestic labour markets. Wages in these industrializing nations are much lower, meaning that non-automation may still remain the more financially viable method.

Labour cost as a percentage of total cost of operation is approximately 40 per cent for Indian call centers and 46 per cent for Filipino centres (Magellan Solutions 2015a). This is significantly lower (see figure 5.2) than the 65 per cent global average (Holamn, Batt and Holtgrewe 2007). Thus, despite the fact that Indian call centre employees spend more time on the phone per customer, labour costs make up a considerably smaller portion of total costs. While call centre employees in the United States can make between US$25,000 and $40,000 annually, agents in India make between $5,500 and $7,000 and between $7,600 and $9,200 in the Philippines (see figure 5.3). These wage differences provide an explanation as to why Indian and Filipino call centres can have nearly double the average handling times as developed nations yet still remain competitive.

Figure 5.3. Range of annual call centre salaries vs. GNI per capita



Sources: World Bank 2017; neoIT 2004.

The question remains as to whether call centres in industrializing nations will continue to rely on labor arbitrage alone, or will seek to reduce labour costs even further through automation via IVR technology. The recent slowdown in the Indian call centre industry seems to imply that the former is becoming less feasible, and that further automation may become necessary. Increased competition amongst industrializing countries for BPO market share may force Indian and Filipino call centres to decrease handling time via IVR technology, thereby reducing employment.

Another possible result of increased competitiveness in the call centre industry is wage reduction – a similarly unpleasant outcome for those employed in the industry. Gross national income per capita is US$3,550 for the Philippines and $1,590 for India (World Bank 2017). Annual salaries for call centre employees in these two countries are significantly above the average income level. Given that the skills required to work as a call agent require little more than English proficiency – a language spoken by large populations in both countries – it is possible that Indian and Filipino call centres may seek to cut wages in order to remain competitive with other countries.

There is, however, the possibility that increased productivity of call centre employees will expand the services provided by call centre companies, thereby increasing employment opportunities to agents that specialize in areas other than customer service. For example, the development of health advisory services has been a relatively new area in which call centres are operating. A large number of nurses graduate in the Philippines each year, and historically many of them have found employment abroad, particularly in the United States (BLES 2003).However, global demand has declined over the past decade, and many Filipino nurses are struggling to find traditional employment McGeown 2012). Many of these nurses are now being hired as call centre attendants to help patients with medical needs over the phone. With new developments in automation, hiring nursing specialists as attendants has become more affordable for call centre companies, thereby absorbing large numbers of unemployed nurses and other medical personnel Magellan Solutions, 2015b). This is an example of how automation can in fact increase employment, particularly among highly skilled workers, reducing call centre operating costs.

5.6. Total automation?

Recent developments in artificial intelligence have begun to raise the question as to whether call centres will eventually be completely automated, entirely eliminating the need for call attendants. Technologies such as chatbots have advanced to the point where they are capable of handling almost all routine tasks currently performed by call attendants. Major companies such as E-bay, Spotify and Bank of America are already utilizing completely automated bots to handle sales, advertising and customer service (Agius 2017).

Despite the fact that chatbot and IVR technologies are already in use by many companies, there are numerous reasons why they are not being fully embraced. Perhaps most significant is a general customer resistance towards interacting with artificial intelligence. Polling shows that the vast majority of US consumers prefer dealing with humans as opposed to IVR or bot technologies (Wharton School 2016). Companies worried about losing customers to competitors due to automated call systems are likely to remain reliant on services provided by call centres. Some analysts suggest that this preference may change as younger generations are added to the consumer pool. This is a very real possibility, as the population continues to become more tech-savvy and comfortable with computer technology. IBM cites a customer service study suggesting that 72 per cent of millennials prefer self-service solutions rather than phone calls to resolve issues. Despite these preferences, however, there are still the technological limitations that make certain tasks exceedingly difficult to automate, and younger customers are still compelled to seek support over the phone (Wharton School 2016).

A second reason why complete automation is not for the near future is its cost relative to BPO services. IVR software can already cost companies thousands of dollars in installation, equipment, and maintenance (Wise 2015). The cost of chatbots is even higher (Rimon and Leap 2016). While these technologies are viable options for large corporations, small and medium-sized firms looking to outsource business operations are still likely to opt for BPO firms in industrializing countries.

As artificial intelligence expands in its capabilities, companies will inevitably continue to incorporate it into their business models. An increasing number of routine tasks will become automated; computers may eventually carry out even more complex work, such as management, public relations and investment (Autor 2015). Advanced forms of machine learning algorithms have the potential to give computers true "intelligence", allowing machines to learn and adapt from experience in a manner similar to humans. By departing from the deterministic archetype that has constrained artificial intelligence thus far, the potential for automation of highly abstract activities (those requiring abilities such as logic, reason, hindsight and so on) becomes a real possibility.

Nevertheless, the ability for computers to perform complex tasks such as forging meaningful personal connections with customers is still far from implementation. There are a variety of fundamental issues that must be resolved before computers can perfectly replace a human in meaningful conversation. In the short term, as long as consumers continue to crave personal connections in business, the need for call attendants will remain, although quite likely at a diminished level.

5.7. Reshoring

Although total automation may not be feasible in the near future, the increased capabilities of IVR technology have undoubtedly weakened the comparative advantage of low labour costs historically enjoyed by the Indian and Filipino industries. Even partially automated systems significantly reduce the amount of time a call centre agent must spend with each caller, such that fewer employees can service the same number of customers. This raises the question as to whether a process of reshoring call centre operations back to client nations such as the United States will begin to emerge due to changing cost structures. Furthermore, market research shows that consumers prefer dealing with call centre agents that are domestically located, due to cultural and linguistic similarities (Magellan Solutions 2016). These customer preferences are another reason that reshoring may indeed be a feasible option, as automation lowers dependency on labour.

As discussed in the previous section, total automation is constrained by technical issues as well as consumer preferences. For this reason, labour costs will remain a significant percentage of call centre operating costs. New technology may reduce the labour-cost advantage of India and the Philippines, but given the vast difference in average industry wage between these two countries and the United States (see figure 5.3), it is not likely to be eliminated completely.

With regard to cultural preferences of consumers, it appears as though call centres in the Philippines have already begun capitalizing on cultural and linguistic similarities between Filipino agents and American consumers. The English spoken in the Philippines is similar to that of the United States, and Filipino citizens are more likely to consume American media than their Indian counterparts (Winn 2014). Industry analysts attribute the recent dominance of the Filipino call centre industry to the shared cultural similarities between Filipino call centre agents and their customers.

Thus, it appears that rather than a process of reshoring, the likely trend for the near future will be growth of the Filipino call centre industry at the expense of the Indian industry. With its advantage in shared cultural similarities with customers over India, and wage advantage over the United States, call centre jobs are likely to continue to flow from India to the Philippines, but not return in great number to the United States.

5.8. Conclusion

Increased automation in the global call centre industry poses a serious threat to BPO firms relying heavily on labour inputs. As IVR technology continues to improve, call centres will increasingly attempt to shorten handling times and reduce labour costs through automation. While this process has been occurring for quite some time, the recent slowdown of the Indian call centre industry is cause for concern.

It is true that India is losing most of its call centre jobs to the Philippines, whose call centre industry also relies heavily on cheap labour. However, this does not mean that automation is not a direct threat to the industry in both nations. As firms in these countries face competition from one another as well as abroad, they will be presented with two options: cut wages or increase automation. The former will of course harm those workers who are currently enjoying a middle-class income from their call centre employment. The latter will reduce the amount of labour required to handle each call, thereby decreasing employment levels.

While the future of Indian and Filipino call centres appears likely to change dramatically, there is still reason to believe that automation will not completely eliminate the call centre industries in the two countries. As discussed earlier, consumers still much prefer human-to-human interaction to IVR technology, and decreasing costs due to automation have allowed call centres to offer specialized services not generally available in the past. The bottleneck for complete automation in the industry appears more related to consumer preferences and operational costs rather than technological shortcomings. With their low labour costs relative to developed nations, call centres in countries such as India and the Philippines are likely to still remain competitive. The more pressing issue is the seemingly inevitable negative impact these industry changes will have on call centre wages and employment.

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Robotics and reshoring

Employment implications for developing countries

Much of the discussion of the impact of automation on employment has focused on developed countries. Yet for developing countries a key concern is the prospect of “reshoring” or “nearshoring” – the opposite of offshoring – in which production shifts from developing back towards developed countries. These shifts would be enabled by automation in the labour-intensive sectors that have provided developing countries with strategic entry points into global markets and continue to employ large numbers of workers, often disproportionately women. The COVID-19 crisis has lent renewed urgency to the discussions on such restructuring of global supply chains. Relatively absent in these discussions is a sense of how automation plays out on the shop floor. This has motivated the industry case studies in this volume, addressing the implications of the increased use of robots and ITC-enabled automation in the apparel and electronics industries as well as in retail warehousing and business process outsourcing.

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