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Automation and its employment impacts: Case studies in Mexico's apparel and footwear sectors

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▶ Abstract

This paper is part of a research project on the effects of automation in the apparel and footwear sectors and their gender dimensions. The main goal has been to improve our understanding of how processes of technological upgrading, particularly automation, interact with local social structures and institutional systems in the apparel and footwear industries to impact women's and men's employment. To this end, in-depth case studies in two apparel and two footwear manufacturing plants, based on interviews with employers and workers, were conducted in Mexico. This paper outlines interview findings with respect to the drivers and barriers to automation in the selected establishments, as well as on the employment impacts of technological upgrading. In all factories, technological upgrading has been implemented in moments of production expansion, and the expansion of demand has more than compensated the expected labour substitution effect of automation. Regarding gender, the absence of labour-saving impacts means that there has been no defeminization of the factories' workforce. In addition, technological upgrading and automation have led to shifts in the skills profile of workers, which could eventually have gender composition effects.

Keywords: automation, employment, gender, Mexico, apparel, footwear

Introduction[1]

The apparel and footwear industries have played a central role in industrialization processes, providing a source of formal employment opportunities in developing countries, particularly for women, where formal jobs are limited (Bárcia de Mattos et al. 2022). In 2019, before the onset of the global pandemic, the textiles and garment sectors combined employed approximately 91 million workers globally, 50 millions of which were women (ILO 2020). In garment manufacturing more specifically, it has been estimated that women account for about 80 per cent of employment (ILO 2019). Thus far, there is limited automation in apparel and footwear manufacturing. In this context, the extent to which technological upgrading, particularly automation and digitization, transform the industry, will have employment implications for workers. More specifically, a key issue concerns the potential defeminization of the workforce which literature suggests often accompanies increases in capital intensity and productivity (Kucera and Tejani 2014; Tejani and Kucera 2021).

The *de facto* and potential impacts of new technologies, particularly automation, on employment and the world of work more generally have been the subject of much debate in academic literature and media headlines across the globe. A lot of research, especially that making headlines, is based on workers occupations, tasks and skills profiles, often attempting to assess to which degree certain jobs (and its subcomponents) are routine and repetitive, and thus arguably at higher risk of automation (see Anzolin 2021; Bárcia de Mattos et al. 2022). Less research has focused on understanding what is happening on the ground at the firm level, using qualitative approaches. Yet, the future of employment across industries, including apparel and footwear, depends not only on technical feasibility of automation technologies but also on a host of other factors such as the relative capital and labour costs, labour availability, skills requirements, infrastructure, logistics, and decision making at different levels and by different actors (employers, workers, managers, etc.) as well as the broader institutional setting where production takes place, including trade policies, the level and location of demand for apparel and footwear, and structural changes along the global value chain (Bárcia de Mattos et al. 2022).

This paper is part of a research project on the effects of automation in the apparel and footwear sectors and their gender dimensions under the umbrella of "Building Partnerships on the World of Work"[2], a project funded by the European Union, and jointly implemented by the International Labour Organization (ILO) and the European Commission Joint Research Centre (EC-JRC). The main goal of this research project has been to improve our understanding of how processes of technological upgrading, particularly automation, interact with local social structures and institutional systems in the apparel and footwear industries to impact women's and men's employment. To this end, in-depth case studies in selected manufacturing plants, based on interviews with employers and workers, were conducted in five countries, namely Germany, Indonesia, Mexico, Romania, and Spain. This paper presents findings from the research on the apparel and footwear sector in Mexico. It first presents the project's background and motivation, including a snapshot of the industry in Mexico, and briefly outlines the research design. It then discusses interview findings. Summary discussion and conclusion follow.

Background and motivation[3]

Technological upgrading is an incremental process, with constant innovation. Enabling technologies (e.g. cloud computing) and new production systems – such as digital sensors, vision systems, advanced material handling tools, robotics and many others – are increasingly available in factories. These factory 4.0 innovations operate autonomously or in collaboration with workers across different stages of the apparel and footwear supply chain. To date, most modern technologies concentrate at the ends of the supply chain, especially textiles on one end and logistics and retail on the other. Apparel and footwear manufacturing remains, thus far, labour-intensive with relatively limited presence of

[1] The authors wish to thank the companies for their valuable support without which this research would not have been possible. The views expressed in this paper are those of the authors and do not necessarily represent the views of the ILO.

[2] Information about the project is available at https://www.ilo.org/employment/Whatwedo/Projects/building-partnerships-on-the-future-of-work/lang--en/index.htm.

[3] Section largely based on Bárcia de Mattos et al. (2022), published by the same research project.

advanced manufacturing technologies. There are, nevertheless, differences between apparel and footwear production, with greater presence of new technologies in the latter, as well as across tasks within apparel and footwear manufacturing.

Today, advances in technologies for the various production steps within manufacturing could have the largest impacts on apparel and footwear employment going forward. Sewing, in particular, concentrates up to two-thirds of workers (Chang, Huynh, and Rynhart 2016). It is also one of the tasks which remains challenging to automate given the malleability of fabrics, and its varying characteristics (Kucera 2020; Kucera and Bárcia de Mattos 2020; Bárcia de Mattos et al. 2021). It has been estimated that material handling accounts for about 80 per cent of overall production time and cost in apparel production (Gries and Lutz 2019).

There have been advances in recent years but, for the foreseeable future, new and old production systems will coexist in apparel and footwear manufacturing (Altenburg et al. 2020; Bárcia de Mattos et al. 2021; Kucera and Bárcia de Mattos 2020; Bárcia de Mattos et al. 2022). A key issue relates to a potential acceleration of technological upgrading and automation and, particularly in developing regions where the industry remains an important source of employment, whether this would result in the defeminization of the workforce which literature suggests can accompany increases in capital intensity and productivity (Kucera and Tejani 2014; Tejani and Kucera 2021).

A number of studies suggest that automation has differential impacts on women's and men's employment, often associating technological upgrading with defeminization. Several studies indicate that manufacturing sectors marked by a feminized workforce experience a contraction in the share of women as production becomes more capital-intensive (Tejani and Milberg 2016; Tejani and Kucera 2021; Seguino and Braunstein 2018; Caraway 2006; Kucera and Tejani 2014). Regarding specifically apparel and footwear, Tejani and Kucera (2021) find negative impacts of labour productivity increases on women's employment within the industry.

This literature proposes various potential reasons behind the decreasing importance of low-wage women's labour in more capital-intensive, technologically-advanced production, including gender norms which designate men as breadwinners and women as secondary workers, and different skills requirements of new industrial jobs coupled with (real or perceived) differences in the skills of women and men (Tejani and Kucera 2021). Still, there is a dearth of research providing evidence for these and other hypotheses. Most often, literature is based on data collected and analysed at the aggregate level. The decisions behind these outcomes and the roles of different actors and institutions in shaping them remains understudied. Little is known also about how the gendered impacts of automation might vary across industries, depending, for instance, on the capital-intensity of production, its amenability to automation or the share of women's employment. The research project within which this paper is embedded is a first step towards building new knowledge and informing future evidence-based policies that address the effects of automation technologies on women and men employed in the apparel and footwear sector.

A snapshot of the apparel and footwear in Mexico

In 2019, prior to the onset of COVID-19, the apparel and footwear industry in Mexico employed over 1 million workers, more than half of which were women – overrepresented relative to their share in total and in manufacturing employment (under 40 per cent). Women's share of employment was particularly high in apparel production, nearly 65 per cent, roughly equivalent to men's share of footwear employment (where women accounted for 34 per cent of workers).

It is an industry marked by relatively low wages and informality. According to CANAINTEX, about 70 per cent of employment in the textile and apparel industry is informal.[4] Overall, in 2019 hourly earnings in apparel and footwear (27.1 pesos) were lower than those in manufacturing (34.6 pesos) and the economy overall (37 pesos). Women were worse off than men. The mean hourly earnings of female employees in apparel and footwear manufacturing was equivalent to about 84 per cent of the average male counterpart in 2019, a gender pay gap akin to the situation of women in manufacturing overall. Based on data from the *Encuesta Mensual de la Industria Manufacturera*, INEGI (2020) concluded that eight products accounted for more than 40 per cent of apparel production in 2019.[5] In terms of economic contributions, 2018 data from INEGI (2019) indicates that wearing apparel accounts for about 70 per cent of the industry's production value, while knitted apparel accounts for 7.5 per cent. Other apparel goods account for 18.5 per cent.

[4] Cohen Sitton, J.; Rayek Mizrahi, V.; Gómez Tames, A. (2018) "Cadena de Valor Sector de la Moda Textil-Confección-Calzado" powerpoint presentation to the Comisión de Economía Senado de la República, 24 Octubre, [Presentación de PowerPoint (senado.gob.mx)](), accessed 15 Sept. 2021.
[5] Including men's pants; knitted t-shirts for men; knitted t-shirts; women's pants; men's suits; women's blouses; sports shirts; and cotton underwear.

The importance of the industry to the domestic economy has been declining. The apparel and footwear industry's contribution to gross domestic product (GDP) contracted since the late 1990s, from 1.4 per cent in 1998 to 0.4 per cent in 2019. The industry's contribution to GDP increased with the establishment of NAFTA, but started to decline from 2000, with the ascension of China to the WTO, remaining below pre-NAFTA levels (INEGI, 2020). In 2019, the apparel and footwear industry's value added was equivalent to 0.2 per cent of GDP and 1.7 per cent of manufacturing value added.[6] In terms of exports, the industry accounted for about 1 per cent of total and 1.3 per cent of manufacturing exports in 2019.[7]

Automation in apparel and footwear manufacturing has been slow in Mexico. Minian, Martínez, and Ibáñez (2017) suggest that in 2004, only 31.4 per cent of apparel companies used automatic or numerically controlled equipment and 0.04 per cent used robots, the remainder used exclusively manual equipment (39.6 per cent) and tool machines (29 per cent). Although newer data are not available, the authors note that productivity has since decreased, mainly due to the production of lower value-added goods. As noted by Moreno-Brid et al. (2021), textiles, apparel and footwear has been a laggard in terms of capital formation and output growth. More specifically, clothing apparel (NAICS code 315) registered an annual average fall of 0.2 per cent in fixed stock capital between 1990 and 2014 (Moreno-Brid et al. 2021).[8]

Still, some studies focusing on the potential impacts of automation technologies in Mexico suggest key occupations in the apparel and footwear industry may be impacted by automation. Minian and Martínez Monroy (2018) apply the Frey and Osborne approach to 2016 data and find that 63 per cent of total employment, 64.5 per cent of manufacturing employment and 87 per cent of employment in the apparel industry in Mexico are at high risk of automation. Tailors and dressmakers, seamstresses and garment makers rank third in occupations with highest risk; sewing, embroidery machine operators and cutting for the manufacture of textiles and apparel goods ranks fifth. Nonetheless, as highlighted by Cebreros et al (2020)[9] this probability of automation is likely an overestimation. Mexico is an emerging economy with a high degree of openness, and automation decisions are influenced not only by technical feasibility, but also by the size of the informal labour market, the wage structure across occupations, and by the interaction between technology adoption and other processes such as the reorganization of the industry and the relocation of production. Firm size also matters, as smaller firms, in particular, have relatively less financial and human resources to invest in new technologies.

Design of the case studies

Following the qualitative research design, the first step was to identify companies which had taken relevant steps in technological upgrading and automation, thus constituting a type of purposive sampling known as extreme case sampling (Etikan, Musa, and Alkassim 2016). Factories were selected in a multi-stage process. Initially, key actors and experts on the apparel and footwear industry in Mexico – including academics, business leaders and public servants – were contacted to get an up-to-date overview of the industry and to help identify suitable companies. An initial list of 11 establishments was contacted, eight factories were visited, and four plants were selected for this in-depth case study analysis.

Factory case studies are based on semi-structured face-to-face interviews and factory visits undertaken by the Mexican authors in mid-2022. The interviews were conducted in two apparel and two footwear manufacturers and encompassed 39 informants. Factory profiles and summary information on interviewees are presented in table 1.

Establishments and interviewees were assured confidentiality and anonymity in the reporting of research findings. Interviewees were partly selected by the factories' point of contact and partly by the research team, based on pre-defined profiles. These included managers, workers' representatives, and workers, including technology specialists within the firm. Interviews followed semi-structured guidelines tailored to each interviewee profile. Discussions with managers and technology specialists encompassed technological upgrading and automation, technology and workers, and general prospects for the future. Worker representative interviews focused on industrial relations and dialogue, technological upgrading and automation, technology and workers, working conditions, training and career tracks. Topics for workers' interviews included workers' tasks, technology and work, working conditions, training and careers prospects, as well as home and work. In all cases, the gender composition of interviewees was carefully managed to reflect the gender composition of the workforce, and gender dimensions were included across all topics.[10]

[6] Refers to ISIC Rev.3 divisions 18 and 19. Source: UNIDO INDSTAT 2, accessed 18 Aug. 2021.
[7] Apparel and footwear refer to SITC 84 and 851. Source: UNCTADSTAT, accessed 20 Aug. 2021.
[8] The figure for textiles (branch 314) was 0 per cent.
[9] Using Frey and Osborne probabilities for automation, Cebreros et al (2020) suggest that 65 per cent of Mexican employment is at high risk.
[10] Fieldwork guidelines and the full set of questions are available on request.

▶ **Table 1. Profile of the establishments selected for case studies**

	Type of product	Business profile	Number of employees	Number of interviews	Role of respondents
Factory A	Apparel	The site includes two interconnected factories which are part of a fully Mexican-owned conglomerate manufacturing and selling industrial uniforms and work clothes, as well as suits and custom-made suits for own brands and international brands, mostly for the domestic market.	1,400 (60% women)	6	2 managers (men); 4 production workers (3 women and 1 man).
Factory B	Apparel	This case study includes two plants working in close collaboration cutting and assembling garments, respectively. The establishments are part of a Mexican-owned, vertically integrated, group. It produces underwear for its own brands as well as international brands, largely for domestic consumption.	1,300 (70% women)	8	2 managers (men); 1 engineer (woman); 5 production workers (3 women and 2 men), incl. a workers' representative (woman).
Factory C	Footwear	The factory is part of a large Mexican footwear group specialized in the production of high-end cowboy boots, fine footwear and leather goods using exotic animal leather, with operations in Mexico and abroad. This site encompasses two interconnected factories producing mostly for the group's own brands and the Mexican market.	1,400 (40% women)	15	8 managers (6 men and 2 women); 7 production workers (4 women and 3 men).
Factory D	Footwear	Large family-owned footwear business employing over 5,000 workers (40 per cent of which are women), and manufacturing 70-75,000 pairs of shoes daily. The firm produces for its own brands, mainly for the domestic market, as well as for international brands. The study was conducted at one plant and headquarters, and part of production for this plant is outsourced to external manufacturing units.	1,700 (n/a)	10	4 managers (men); 2 engineers (men); 3 production workers (2 women and 1 man); 1 business chamber representative (man).

Source: Authors, based on information shared by informants.

Description of firms

Factory A is part of a fully Mexican-owned conglomerate manufacturing industrial uniforms and work clothing, as well as suits and custom-made suits for its own brands and international brands. Production targets largely the domestic market with roughly 10 per cent exported to neighbouring countries. The site selected for this study encompasses two interconnected factories producing business uniforms, jackets, and vests in Mexico State. It engages approximately 1,400 direct employees and 30-35 contractors operating in external workshops. Roughly 60 per cent of workers are women and 40 per cent men (mainly in cutting and ironing) according to interviews with managers. The majority of workers have secondary education, with most managers being university graduates, and workers are organized in a formal, recently formed, labour union.

Factory B is also part of a Mexican-owned, vertically integrated, group. The conglomerate owns six garment plants, one cutting plant as well as a plant producing textiles. Moreover, like Factory A's group, Factory B's conglomerate owns many sales points across the country. The firm produces underwear for its own brands as well as other brands. Factory B's main market is domestic, exporting roughly 15 per cent of its output. Located in Hidalgo, the site selected for this case study includes two plants working in close collaboration cutting and assembling garments, respectively, engaging a total of 1,300 employees. According to management, about 70 per cent of workers are women and 30 per cent are men. Of its approximate 300 engineers, many of which are middle managers, 70 per cent are women. Workers are unionized.

Factory C is part of a large Mexican footwear group specialized in the production of high-end cowboy boots, fine footwear and leather goods using exotic animal leather. It produces mostly for its own brands, with eight firms specialized in specific products and markets. The conglomerate is vertically integrated, owning from exotic animal farms and tanneries to production plants and stores. Located in Guanajuato, the site selected for the case study encompasses two interconnected factories producing goods to order (rather than for stock) for the domestic market and exports. The first factory produces cowboy boots and employs 1,000 workers, the second, with 400 employees, manufactures fine shoes. According to a manager interviewed, approximately 40 per cent of workers are women. Workers are not yet unionized but will become so soon, as required by the recently passed labour law.

Factory D is a large family-owned footwear business employing over 5,000 workers (40 per cent of which are women), and manufacturing 70-75,000 pairs of shoes daily. The firm produces for its own brands, largely for the domestic market, as well as for international brands, particularly for exports to neighbouring countries. Technology is at the center of the firm's business proposition. The case study was conducted at a manufacturing plant which employs 400 workers, as well as with headquarters, engaging 1,300 workers. Part of production for one of these plants is outsourced to external manufacturing units.

At Factory A, the production process starts with the development of pattern design, including the digital planning for cutting fabric. The fabric is then spread and cut. Following, the interlining is fused to the outer layer of fabric. The piece is then sown into a finished product. Automation started being introduced in different processes in the early 2000s, with the purchase of automatic cutting and ironing equipment, after which electronic attachments (e.g. computerized panels) were introduced to transform sewing machines into semi-automated machinery. Semi-automatic machines with laser-light for greater precision in placing components for sewing were also introduced. Decisions about the purchase of new equipment and technological upgrading are taken at the corporate headquarters, based on recommendations from a committee of senior directors, in consultation with engineers in house as well as outside experts.

The level of technology used (manual, semi-automated, automated) depends on the stage of the production process (design, spreading, cutting, fusing, sewing, ironing), the task or operations within these processes, the fabric used and the type of product. At Factory A, pattern design and development are carried out with digital machinery. Rolls of plain fabric are spread automatically, and cutting is done with modern, automated machines with steel-blades. Most of these machines are used for mass production, but one is devoted to the production of tailor-made suits. Checkered and plaited fabrics, and combed textiles, which are more delicate, are spread and cut manually. Afterwards, a worker places the cut fabric and interlining on the fusion machines, which are all automated. Sewing comprises a long list of sub-operations. For example, in the case of suits, it includes selection of front and back, sleeves, pockets, necks, trims, all of them to be assembled in a carefully designed step-by-step order, to produce the final garment rid of extra threads and rims, with its final touches and revisions to then be ironed. These operations use very different machines, some of them are automated and carry out various tasks. Others are semi-automated machines with electronic screens attached, and there are also manually operated tools and equipment, such as for necks and some trims which require very fine details that the automated machines cannot reproduce.

At Factory B, rolls of fabric are first laid out by hand, and then cut automatically. Cutting is organized in batches according to size and colour, which are sent in bundles to the assembly plant. There, the cut pieces are sewn. Finally, the undergarment is sent to quality control. In the 1990s, the company acquired electronic attachments (i.e. panels) to convert electro-mechanical equipment (for cutting, sewing and embroidery) into semi-automatic machinery which allows for the programming and controlling of activities and parameters. Today, operations rely on a range of equipment with various degrees of technological sophistication. Digital systems are used to create patterns, and assembly is simulated and planned using a 3D system. Cutting is done by automated machines, as is embroidering – a worker feeds the machine which carries out the embroidery process autonomously. In sewing, the firm uses a wide variety of equipment: mechanic with no electronic panel (for waist tying operations), semi-automatic with a programmable panel, and autonomous (for embroidery). Upgrading is done gradually, depending on the need to improve efficiency and reduce costs, the strategy to address labour force scarcity in the region, and the financial capacity to make the required investments. Investment decisions are taken at the conglomerate's headquarters.

Factory C first prepares leather for cutting, after which the pieces are embroidered and engraved. The pieces are then backstitched and assembled. Finally, accessories (avios) are placed, and products are finished and adorned. Automated equipment was first introduced in 2007/08. Automated machines are used for sewing, backstitch and embroidery, with workers feeding the machine for processing. Semi-automated machines, availing of electronic panels attached to mechanical equipment, are also in use in sewing and heel reinforcement, backstitch, and assembly of some products.[11] Most of the cutting is done manually, due to irregularities in exotic leather, but some is done using automated laser cutting machines. As a rule of thumb, machinery for boot production at Factory C is updated every five years. Moreover, design is done digitally, and the company uses enterprise resource planning (ERP) software for management and product traceability. Sales are also digitized, including management of logistics and distribution. Informants noted that technological upgrading was linked to a strategic shift in the company's business model; decisions are taken at headquarters and upgrading financed with own resources.

At Factory D, footwear is first designed, prototyped, and tested before rolling out to the production line. In production, fabrics are layered on special tables and components are drawn to minimize waste. Following, layered fabrics are cut (manually using templates, or with semi- or automated machinery) and leather components are mounted and tamed. Next, pieces are embroidered, and interlining is added with semi-automated equipment. Backstitch operations are carried out with semi-automatic machines that have digital attachments like control panels and touch screens. Insole preparation follows (including attaching it to the shoe upper) using semi-automated machines, robots and direct injection. Finally, the footwear is fully assembled, dried, ornamented, and polished and packaged, before it is transported to the warehouse. Decisions on the acquisition of new equipment are made by a committee created approximately seven years ago, with representatives from various departments. Upgrades are financed with own funds and from 2023 onwards, the committee will have a dedicated budget line.

The factories selected for case study have not been immune to the economic crisis onset by the COVID-19 pandemic. Factory A restricted its activities to the manufacture of medical uniforms, reduced its workforce by more than 500 posts and many of the conglomerates' sales points were closed. In 2022, as the economy recovered, the firm started to expand employment to meet growing demand. Activities at Factory B were also negatively impacted by COVID-19. Workers stayed home for two months or more, receiving 50 per cent of their salary. According to a manager, Factory B had already started investing in digital technologies for marketing and sales before the crisis, mitigating some of the potential negative impacts of the pandemic. Factory C also reduced production, laid off workers and subcontracted work. With recovery, production ramped up (from 200 pairs of shoes per day to 1,000) and employees were called back, but part of production remains subcontracted to external workshops. Factory D's daily output fell to approximately 50 per cent during the COVID-19 pandemic, and 500 jobs were lost. According to interviews, negative impacts during and after the pandemic were mitigated with new contracts to produce for other brands, often in lieu of factories located in China and Russia.

▶ Interview findings

Factors driving and hindering technological upgrading and automation

Drivers

Production across all factories studied relies on mixed equipment, ranging from those operated manually, to semi-automated and automated machinery. Automation in various processes is associated with several benefits. Interviewees remarked that it improves output quality, productivity and is critical to remain competitive. Moreover, labour shortages in the industry and difficulty to attract young workers was consistently reported to be a key driver of automation.

[11] Backstitching provides an example of the differences between automated and semi-automated equipment. Automated machines cut the thread and generate the seam for backstitching, others do the edging to prepare the backstitch. Semi-automated machines – i.e. sewing machines with digital touch screens – count stitches, cut thread and tie it.

At Factory A, technological upgrading responds to a need to augment productivity and output capacity. In 2021, the factory produced a daily average of 600 suits. In 2022, the plant was manufacturing nearly 2,200 suits daily, with the expectation of further increases in 2023. Technological change is also expected to compensate for a shortage of skilled labour and lead to greater profitability. As a manager in Factory A indicated: "*We experience shortages in manpower as young people do not want to work in factories in repetitive manual tasks*" (male manager, Factory A). Finally, new machinery is expected to have lower energy needs thus contributing to lower energy costs (noting also solar panels were installed at the factory).

Interviews with Factory B point to similar factors driving automation, including cost effectiveness and increases in profitability, as well as competitiveness. Shortage of skilled labour came up as a determinant factor, as did improving working conditions.

Competitiveness, productivity, quality, and speed are also among the automation drivers highlighted in interviews with managers at Factories C and D: "*Nowadays it is not an option if you want to be fighting. We are expanding, it is not to have fewer people, it is to make workers more flexible, streamline processes*" (male manager, Factory C); "*The most modern machine allows you to give the customer a product they are used to, of very good quality and delivery time.*" (male manager, Factory C); "*Automated machines improve the speed and volumes of production as well as the quality of our shoes.*" (male manager, Factory D). At Factory D, it transpired that technological upgrading in some operations was also driven by labour cost: "*In cutting, the decision to invest in more automated machines were cost efficiency and labour saving*" (male manager, Factory D).

Across the four factories, there were several common drivers of automation highlighted by our interviewees. Managers in the apparel and footwear industries in our study repeatedly voiced their concern with labour shortages. They attribute those shortages to the lack of interest the industry generates among young people:

> *"What I have seen in my many years of experience in the industry is that youngsters have become less and less interested in jobs in manufacturing, and even less in the footwear industry vis-a-vis say the automotive industry. The work in our industry requires a lot of undivided attention, doing rather repetitive tasks for hours within closed doors... where it is hard to use or look frequently at your cell phone or other screens." (male manager, Factory D)*

A male manager from Factory C stated that considering the shortage of workers, automation allows the company to move their workforce to different operations: "*Today in the state of Guanajuato we have a shortage of people, by automating a process we can move people to other functions... My production process is traditional, and I prefer to take advantage of people in various operations*". The nexus between automation and labour shortages was reaffirmed in interviews with Factory D, e.g. "*The firm's commitment to automation is driven by the scarcity of workers, in particular in backstitching*" (male manager, Factory D).

Noting that the apparel industry is less automated than textile manufacturing, a manager in Factory B suggests the varying degrees of automation are linked to the standardization of goods, or lack thereof. He argues that in apparel manufacturing there is greater semi-automation whereby machines and workers collaborate towards greater efficiency and quality:

> *"In the apparel industry there are some operations that are more automated and there are some that are less; basically because of the degree of product standardization... when you produce more standard products, automation is justified... there is, I would say, 'semi-automation' in the sense that you do not displace the employee, but you increase his or her efficiency and improve the production process in all aspects: quality, efficiency, effort." (male manager, Factory B)*

Factory C interviews indicate that, initially, the modernization of production, with regular technological upgrading, was linked to a shift in the conglomerate's business model, which includes a commitment to automate production processes. To this end, the establishment actively interacts with equipment suppliers to developed machinery adapted to the factory's needs. Moreover, although the company produces less pairs of boots than twenty years ago, these are more complex products, according to a manager.

Commitment to lean production has also driven Factory D group's automation efforts since 2019. Moreover, the group has a corporate long-term view on the key role of automation. A manager expressed the firm's view of automation beyond installing new machinery:

> *"Automation goes well beyond the introduction of new electronically controlled machines. It implies, too, a change in the system of production to adequate it to the operations of the automated equipment... you*

are talking about the introduction of numerous technological/organizational changes in the firm, associated with the installation of the new machines, and thus you are talking about the introduction of an automated system of manufacturing, not of automated machines in the same old process of production. It is in only in this way that the move towards automation solves the needs of the firm.” (male manager, Factory D)

Such approach makes Factory D a proud tester of new machinery before committing to its rollout. As stated by a manager, “*Given our excellent prestige as customers, machine manufacturers send us from time-to-time machines on a try-out periods, to ask us whether they are suitable for our manufacturing processes*” (male manager, Factory D).

Barriers

Along with drivers, there are several barriers that limit automation processes across the establishments interviewed for our study. Cost is key among the barriers to technological upgrading. Managers from Factory B indicated that options to further automate production have been found not to be cost-effective, particularly in the context of Mexico where labour cost are relatively cheap and producers of capital goods are located abroad, which means that they tend to be “technology takers”. Similarly, interviews with Factory D suggest that the market share of a factory makes it unprofitable to automate even all the operations which are already technically automatable. Generally, the establishments interviewed depend on their own financial resources to invest in new technologies, absent industrial policies to foment this innovation. As stated by a male manager from Factory B: “*There is automation that is profitable, that makes sense, and other that does not. If it makes sense, automation is deployed throughout the company*”.

The degree of automation at the operational level depends on the level of standardization of a task or product. Some operations, like cutting, lend themselves more easily to automation and technological upgrading, whereas other operations, such as sewing, are harder to automate and have seen less progress. Impediments are linked to the pliability of fabric, the existence of small parts, and the constantly changing products to respond to ever-changing demand. Even when design is computer-assisted, this does not imply that the production process becomes automated, as evidenced in the following excerpt from a manager’s interview:

“I believe that there is little that can be done in sewing, in cutting, yes, in speeds, but in the digital transformation and design part we are at the forefront, so in 3D there will be a little more [automation] and you can still include all the connections between phases.” (male manager, Factory B)

Type of product can also be a barrier to automation. Several of the factories produce goods tailored or marketed as handmade. Factory C markets handmade high-end leather footwear, which limits the extent to which automation technologies can be used. As summarized by a male manager at Factory C “*For me it doesn't make sense to automate more because a lot of our stuff, that is, what we sell is the artisanal part, which is still done as it was done years ago*". At Factory D it emerged that there are niches where the image or the reality of handmade shoes is more profitable despite being more costly. There are similar limits to automation at Factory A to the extent that it produces tailored suits and fashion products in small-scale. Automation is thus limited to standardized sub-operations, as stated by a manager:

“Standard processes can be automated. In apparel manufacturing, although fashion forces frequent modifications, there are many operations that are quite standard. For example, sleeves are made separately so are their eyelets and 'angles', as well as the gluing of some components in the necks or elbows, all are processes of few rather standard operations.” (male manager, Factory A)

Production volume and physical size of pieces are also factors which limit automation. Factory B interviewees noted that the factory is most competitive in fashion underwear which is produced in limited quantities and responds to fashion trends (in contrast to evergreen products which China mass produces at lower prices). This type of production would require flexible machinery, combined with craftsmanship in sewing. Similarly, at Factory C automated embroidery machines are used in the production of larger pieces with high production runs whereas small pieces and lower volumes are made using semi-automated equipment, with workers playing a more active role: “*For larger pieces and more volume, autonomous embroidery machines, with 12 heads, are used. In contrast, for small pieces semi-automated and more individualized machines, but also with a panel, work better, like for the embroidery of ears*." (male manager, Factory C)

According to a male manager at Factory A, seasonality can also limit automation, as the fashion market is characterized by rapidly changing demand, while the automated machines are so far not versatile enough to allow for rapid response:

"*In manufacturing, garment products change seasonally, requiring significant modifications and transport of finished as well as in-progress pieces*".

More generally, declining or uncertain demand could also be a barrier to automation, which, as explained above, takes place fundamentally to respond to increased demand. Several interviewees pointed out that only a sufficiently dynamic and persistent demand, which is currently lacking for some products, would make it profitable to modernize the equipment towards more automation.

Materials remain a barrier to automation. As mentioned above, at Factory A, plain fabrics are cut by automated steel-blade machines whereas manual cutting is used for checkered or plaited fabric as well as combed textiles. At Factory C, irregularities in exotic leather prevent the automation of cutting, whereas the technology is available and used for some leather and other materials. A manager at Factory D also noted that difficulties to the automation of leather processing remain. According to the manager:

> *"Industry 4.0 has somewhat accelerated in recent years in footwear manufacturing, but it has still very limited scope specially in leather processing. [Good] leather shoes are still very much a product of artisans more than of industrial workers or automated machines. Augmenting the scope of automatization is a challenge of the leather shoe manufacturing not only in Mexico but worldwide." (male manager, Factory D)*

The need to change layout, and its associated costs, could potentially be a barrier to further automation. For example, technological upgrading at Factory A required significant modifications of the plant's layouts and work organization. At Factory C, the combination of new, autonomous machinery and increasing demand resulted in shifts in the configuration of the production process, as summarized by a male worker: "*As a result of automation and increased demand, there have been changes in the production layout: before the plant only had one mounting rail and now it has three*".

Lastly, at Factory D, when the first automated backstitching machines were introduced, nearly 20 years ago, there was strong resistance, particularly from middle managers. According to interviews, the learning curve to operate them was steep and workers resisted for nearly two years. This suggests that worker resistance can be a barrier, though the situation today is markedly different from that of two decades ago.

Outlook

Looking to the future, Factory A managers indicate that the company is committed to increasing automation and digitization to meet market demand for greater quality at low prices. Some of the factory's production relates to handmade suits which, by definition, limits automation. Nevertheless, the establishment expects to introduce automated transportation lines to move products along the production line, and to introduce automation for standardized sub-operations.

> *"My aim is to implement processes where some operations are done by automated machines; but I am aware that in garment manufacturing one will never be able to automate all its 120 operations. I will start by the automation of some groups of few operations (three to four) and move on with automation as far as I can in the chain. Carrying out this task, I believe, will take me the next five or six years". (male manager, Factory A)*

Factory B managers also stated that the goal is to continue to increase automation and digitization, though there may be limits linked to the production of constantly changing fashion garments. In a similar vein, interviews with Factory C indicate that the type of goods produced (marketed as handmade) hinders potential automation, even though the establishment has been and is committed to increase automation and digitization.

Like in Factory A, informants at Factory D explicitly stated that the footwear industry is unlikely to become fully automated. Still, there seems to be consensus that to remain competitive, the factory will need to continue to upgrade production technologies and further automation. As stated by a manager, "*One must recognize that automation is a necessity for the firm's survival in the future. In some operations it will substitute labour, in others, it will expand it*" (male manager, Factory D).

Technological upgrading and automation's impacts on employment

Job displacement

The establishments interviewed acknowledged that automation technologies substitute labour. At Factory A, automatic spreading has been associated with a reduction in the manpower dedicated to the activity. Similarly, the labour input required for automated cutting is lower. It was estimated by a manager that each automated cutting machine can substitute between eight to ten workers. However, given that the adoption of new machinery has taken place at times of a boost in demand, it has not been accompanied by a decline in the number of factory workers, but rather by the reallocation of the workforce across tasks. At Factory D, similarly, engineers remarked that recently added robots for direct injection and for cleaning the moulds decreased the number of workers needed for these operations from 25 to 8. Yet, as in other cases, workers have been moved to new tasks, some created by the operation of the new machines and others by the expansion of output. Likewise, at Factory B, while it is accepted that automation substitutes some labour input, technological upgrading in context of market expansion has resulted in the reassignment of workers to different tasks, often accompanied by training. Overall, according to a manager, automation has been accompanied by an increase in the number of employees.

The dynamics of job destruction and creation are summarized in the following excerpt from an interview with an engineer at Factory D:

> *"Our automated machines substitute some workers, but at the same create other positions with different qualifications, in particular to operate the machines and to give them maintenance. And the automated machines allow Factory D to produce more and meet higher demand; thus, their introduction may create employment in net terms. To the extent that these new workers are more qualified, their remunerations will be higher. So, more than a net substitution effect of labour by automated machines, we have trade-offs, it destroys some jobs, but it creates other jobs" (male engineer, Factory D)*

Skills

In the absence of a net displacement effect, the introduction of new machinery has generated upskilling and deskilling effects, often resulting in multiskilled workers. As evidenced in interviews with Factory A, the tasks of many workers became simpler. It was reported that training a worker for manual cutting requires 16-24 weeks while a worker can be trained to operate an automated cutting machine in 2-4 weeks. Operating automated machinery, such as automatic cutters, requires on-the-job training but can be done by workers with elementary education, as evidenced by a worker interview at Factory B:

> *"... when a new machine is installed, I ask myself: Do I dare? It´s something new, yes, but I find it interesting to know new things. The firm always offers me the option of learning new tasks and moving to different sections of the manufacturing process. And even though I have only elementary studies [primary levels] I find it easy to move from one section to another. Thank God!" (male worker, Factory B)*

With automated machines, the worker oftentimes becomes a "feeder" of materials and intermediate components to the machine, which carries out the sophisticated processes.

> *"The fusion machines are automated; bands are continuous. The worker places the fabric and the interlining pieces in the band, which enter the chamber where, with heat and pressure, they are fused in the garment. The piece of garment, thus processed, is received by another worker who stuffs it and places it in the sewing line to be further processed." (male manager, Factory A)*

At the same time, the conversion of manual to semi-automated equipment required skills upgrading. For instance, electronic panels added to some sewing machines require that operators learn to operate computerized screens, in addition to the traditional dexterity required for sewing. For example, at Factory A, semi-automatic sewing machines have a laser-light to place the components with more precision, but the operator is still required to carry out the sewing process, manually guiding the fabric. Yet in other instances, such as for operating the robots installed in Factory D, workers with specialized training are needed.

In some cases, the introduction of new machinery changes skills requirements and the educational profile of workers. As remarked by a male manager at Factory D "*With more automation…new abilities are needed, more soft skills and less manual craftsmanship*". When discussing direct injection technology, the same manager added: "*The machines are more cost efficient, may save some type of labour but require other type of workers, in particular in middle management. They have to be better trained (high school at least), tend to be younger and with more knowledge of informatics*".

Interviews in Factory A and Factory B revealed that technological upgrading is often accompanied by greater worker flexibility and capacity to multitask, which means that any worker, irrespective of their gender, can be allocated to different tasks or operations. This helps factories in dealing with labour scarcity and absenteeism. As summarized by a male worker from Factory B "*The majority [of our workers] knows how to handle all machines, we know everything, because we have the capacity. It's the same, but with different programs and machines*". The following excerpt from a worker interview at Factory A suggests the situation is similar:

> *"I just entered Factory A this year… I finished high school… the operation of the machine doesn't have much difficulty… I started working here when the machine arrived, both from scratch. We had a lot of training and tests in terms of papers, interlining, etc… The tests allowed us to identify better practices, to pinpoint what works best for us… there was a lot of support. Basically, by now I know the whole area, I know the laying, cutting, trimming, fusing, packaging, tailoring, etc. I am always adapting to the processes." (female worker, Factory A)*

At both apparel factories, training is provided when new equipment is installed. At Factory A, while training may be initially targeted at those who will operate the machine, other employees working close to this equipment are also given an overview of its functioning and expected impacts. At Factory B, machine vendors train workers when new equipment is installed, these workers then train colleagues, in a cascading system.

Multiskilling is at the center of training at Factory C. Onboarding training takes three months and each worker learns a minimum of three tasks. Further, interviews with managers revealed that due to labour shortages, the skills requirements to enter employment at the factory are low, and workers are trained once hired. Moreover, the establishment has made efforts to include vulnerable groups of workers, such as persons with hearing impairment, in their workforce. The focus on multiskilling was reinforced when new technologies were introduced, and displaced workers were retrained to work in other tasks. As is the case in Factory B, equipment suppliers provided initial training for the operations of new machinery. Factory C's approach to multiskilling is summarized in the following statement: "*Many apprentices learn several fractions [tasks] at the same time and we locate them when spaces open up. It is sought that they are multi-fractions. Human resources take an inventory of what multi-skills each person has.*" (male manager, Factory C)

In some of the factories, training opportunities allow for career progression. Factory B offers training to workers for the operation of new machines, as well as for workers to learn new tasks and for continuous improvement. At Factory B, training enables career progress as evidenced in the following account of a worker on her career progression at the factory:

> *"When I entered, they put me in the 'straight' sewing machine… they trained me to sew fabric bias… this machine did not have a panel… Right now, we have a panel but at that time there was none… They had already begun to change machines. I was in rod cover, zigzag… all mechanical machines …they trained me… until I got here to development of prototypes… I liked using the machines with panels… to identify different types of seams on the screens, it's much more practical and more comfortable than with the mechanical ones… At the end the result is the same." (female worker, Factory B)*

Training is also linked to opportunities for career advancement at Factory D, according to a manager:

> *"… specialized workers in footwear production are scarce. We thus train them from scratch, starting from positions at the bottom of the qualification scale and providing them opportunities for promotion… [In the training process in this firm] youngsters work for certain weeks or months in diverse sub-operations – as they call them, 'fractions', starting from easier tasks and shifting to more complicated ones, in principle all the way from job post number one to job post number ten at the top of manufacturing operations" (male manager, Factory D)*

Factory A also offers training opportunities linked to new tasks, improving output quality and team building. More generally, Factory A interviews suggest that the introduction of semi- or fully automated machines offer workers the possibility of acquiring more, different skills and of having the capacity to execute multiples tasks. As work becomes more flexible, workers cover more operations, which brings with it the possibility of wage rises.

> *"I started ironing, then I went to the fusion machine. I also now have the skills to carry out other tasks, e.g. half-moon as there is not much work, we must be very skilful and ready to do different tasks and operations. That is why managers began to teach me how to operate different and new machines. And as I acquire such abilities to handle the machines, I have a somewhat higher salary" (worker_F, Factory A)*

Training can also lessen potential resistance to technological upgrading and automation by teaching workers the objectives of the new technologies, promoting the notion that technological and organizational changes are for the benefit of both the firm as well as workers. As summarized by a male manager from Factory D "*Before introducing any technical change, or installing a new machine, workers are trained to understand the rationale and know the benefits it will bring to all members of the company*".

Another dimension impacted by technological upgrading concerns physical requirements of work, which could make some operations more amenable to women. In Factory B, it was argued that semi-automated sewing machines decrease the physical strain of workers. Whereas with a traditional overlock machine a worker needs to use both feet, the semi-automatic machine stops automatically, thus requiring the use of a single pedal. Moreover, according to a female manager, training is quicker for semi-automatic sewing machines relative to mechanical equipment, allowing for greater efficiency and thus higher earnings. It was also remarked by a manager at Factory D that some automated machines do not require significant physical effort for their operation, which, the manager proposes, may lead to a greater proportion of women in formerly physically demanding tasks.

Contract type and wage scale

Another aspect of employment quality relates to contract type and pay. At Factory A, technological upgrading has not been linked to changes in contract type or the wage scale. Employees are hired as formal wage workers, as mandated by the federal labour law, with a base pay linked to the federal minimum wage, adjusted according to the tasks executed (better pay for more skilled work) and performance (piecework). Wages at Factory B are defined in a similar manner. All Factory B employees are formal wage workers, with a base pay equivalent to the mandated minimum wage, which is adjusted according to the task performed, plus a performance bonus based on the number of pieces produced by the worker. In both apparel factories, workers are first hired for a three-month trial period, after which they become permanent (long-term) workers.

Similarly, at Factory C, pay is linked to the task performed, based on skills requirements, regardless of the technology used. Wages are the sum of a base wage and a performance bonus (piecework). At Factory C, it was noted that workers' benefits exceed those defined by labour law. After a three-month trial period as contract workers, workers become long-term employees. At footwear manufacturer Factory D, workers' wages depend on the task performed, workers' productivity, punctuality, and quality of output, with benefits beyond legal requirements. Factory D conducted a comparative evaluation of the dexterity required for each job/task in the sub-operations of manufacturing, and those of higher difficulty were linked to higher pay – this is not directly linked to the type of equipment workers operate or the degree of automation. As stated by a worker *"...some tasks that require more specialized manual work are paid more*" (female worker, Factory D), examples include sophisticated backstitching operations.

Although no change in the wage scale appears to have taken place with technological upgrading, as evidenced in the discussion on skills, training and career progression, at least some workers experienced greater pay because of changes in the tasks performed, linked to automation. A worker from Factory D says:

> *"I started when I had only a high school diploma, working at a low level... later I saw a coworker operating an automated backstitching machine. I told my supervisor that I wanted to learn how to use it. He told me that I could take a training course... So, I did, with the support of the company. We were seven trainees in the course. It lasted a year, during the pandemic. At the end, only three of us were chosen for a job at the firm. I now work as a technician specialized in backstitching... now I am at the plant, in the lab where we build the prototypes of new pallets, and I can program them to execute the stitching... I am an instructor for colleagues on how to operate such machines... working with automated equipment is a*

great satisfaction for me... I was put in charge of launching the production line for a client, it took me three months ... my wage rose in my new activity." (female worker, Factory D)

Moreover, to the extent that the skills profile and composition of the workforce changes with, on the one hand, greater need for engineers and specialized skills and, on the other hand, deskilling, new technologies and automation can impact relative wages, leading to a potential polarization.

The imperative for better working conditions and wages arose in an interview with a representative from *Centro de Investigación y Promoción Educativa y Cultural* (CIPEC), for the entrepreneurs of the footwear industry in León as a whole: "*although they are eager to recover the pre-pandemic levels of output and employment, workers in the city show no such strong interest to be employed in this industry. Thus, the footwear industry must realize that, if it wants to attract and retain well-trained workers it must offer better wages and working conditions*".

In terms of social dialogue, Factories A and B workers are formally unionized. At Factory B, in addition to meetings between the trade union representative and management, there are also human resources activities to assist in the resolution of complaints as well as for general communications on work-related issues. Dialogue between workers and management at Factory A can also be done through the trade union, or more informally via factory floor supervisors who are constantly communicating with workers. Interviews also indicate that human resources take an active role in communicating with workers, including through surveys on job satisfaction.

Trade unions are mandated by law, yet, although in some cases workers are unionized, unions do not appear to play a significant role in shaping employer-employee relations. In many factories, as well as in the chamber of footwear manufacturers, interviewees noted that Mexico's new labour reform as well as the USMCA have as a priority that free elected trade unions be present in all industries and play a significant role.

Gender dimensions

As mentioned in the description of the firms, the workforce of all factories is feminized, in line with the composition of the sector overall both in Mexico and abroad. Gender segregation across tasks is also a common reality, for instance, most workers in sewing are women while cutting is disproportionally male.

Both apparel factories under study state that there are no gender limitations in the hiring and placement of workers across tasks, with the potential exception of tasks which require physical strength. Yet, at Factory A, workers in cutting and ironing are predominantly men, whereas those in sewing are predominantly women. Likewise, although Factory B does not have gender requirements associated with job posts, most workers in cutting are male, while sewing is markedly female. There has been, however, an increase in the presence of men in sewing activities, reaching 20 per cent of workers. According to the managers, this was the result of requests by men and not associated to the degree of automation in sewing.

Similarly, managers from footwear Factory C stated that the company does not have a gender preference for tasks. However, as in the apparel factories, certain tasks concentrate workers from a specific sex, e.g. the majority of workers in finishing are women whereas the majority of workers shaping heels are men. This is, as evidenced in the excerpt below, linked to stereotypes which attribute certain characteristics to women and men:

"However, some tasks are showing some patterns in regard to the proportion of women or men performing it. For instance, the company considers that women take better care of details and assigns them to the tasks of finishing and decoration; there are other operations where there are many men and suddenly you see a woman doing the same type of work. Women are more delicate at work, more fixated on details" (male manager, Factory C)

Stereotypes related to gendered characteristics also appeared in Factory D interviews. A women worker stated that women tend to be more careful than men when backstitching, embroidering, ornamenting, and sewing. An engineer noted that the presence of men in an operation historically feminized, final ornamenting, is growing, and this has been met with some resistance. A manager at Factory D recognized that cultural norms play a role in the gendered division of labour within the factories. According to the manager, "*except in some physically strenuous operations, the share of women tends to be culturally determined and not related to differences in productivity or in capacity of men and women*" (male manager, Factory D).

All this means that, at least in the short term, persistent gender segregation patterns mediate the gender impacts of technological upgrading, instead of leading to changes in the gender composition of the workforce in different operations

– i.e., instead of breaking gender segregation patterns. As cutting operations move to automation, for example, it is men that become deskilled as this operation remains male-dominated. Likewise, sewing remains female-dominated despite technological upgrading.

In the medium term, increased multitasking might contribute to breaking gender segregation patterns. A worker interviewed indicated that training is equally accessible to all, and that it leads to worker mobility:

> *[I] "entered in assembling and went on to leather finishing... They trained me for the new machine... If you want to do other things, they teach you to do more things, they allow you and train you. There is no different treatment for men and women, everyone is treated the same." (female worker, Factory C)*

Interviews suggest that working hours for most workers have not been impacted by technological upgrading, with the exception of some workers operating new 24-hour equipment. Factory A working hours are long (8:00 to 18:00, weekdays) and remained unchanged with the introduction of semi-automated and automated equipment. No changes in working hours (7:30-18:30, weekdays) were reported at Factory C, despite an increase in output. At Factory B, automated cutting machines operate 24/5 with workers allocated to three shifts. Night shifts are mostly taken by men. At the assembly plant, the introduction of semi-automated sewing machinery has not impacted working hours, which remain 8:00-17:45. Like in Factory B, in Factory D the introduction of state-of-the-art robots for direct injection and for cleaning moulds operating 24/5 requires a specialized worker to constantly monitor robots.

Even if working hours remained unchanged, this does not mean favourable working conditions for women. Contractual working hours are very long, which means that they have to leave their homes very early in the morning and come back at night. It is also common practice to impose additional work hours weekly, over and above those specified in formal contracts, to meet production targets. According to a male manager at Factory D, *"... the industry has a tendency to impose long or extended work hours: a tendency that is unfavourable to women and makes it more difficult for them to have compatible, functional work-family commitments on a day-to-day basis*". In this context, the company is reported to have been successful in hiring more women by offering shorter shifts of six hours per day. Another option reported as popular with women who take night shifts is to work four nights per week, resting on Fridays, Saturdays, and Sundays. Moreover, the firm offers transportation and is reportedly in the process of providing day care for small children.

With regards to pay, and perhaps related to the degree of responsibility or expertise required, there may be a more favourable treatment of managers vis-a-vis production workers regarding the evolution of benefits and wages at Factory D: "*... we [managers] always get a wage rise to compensate for inflation... and a bonus according to the firm´s annual profits...*" (male worker, Factory D). Whether this bonus is proportionately the same for lower-placed workers is unclear. This dimension is even more important if one considers that women are present but underrepresented in management positions, thus suggesting potentially greater gender disparities in earnings.

▶ Discussion and conclusion

A mix of technologies was found in each of the factories in this study, with various degrees of sophistication and ways in which machines and workers interact. Mechanical equipment connected to a source of electricity (e.g. traditional sewing machines) facilitates some tasks which continue to require active worker involvement. Some machinery is semi-automated, with electronic panels which can be programmed by the worker to assist and guide their work. Finally, automated machines are capable of autonomously carrying out certain tasks, with workers "feeding" them material and monitoring their work.

A number of common drivers and barriers to technological upgrading and automation were identified in the interviews across factories. Common drivers of technological upgrading include greater productivity, efficiency, and quality. Addressing labour shortages emerged as a critical consideration. Modern technologies, including automation, also appear to be key for competitiveness. In turn, barriers which inhibit automation in both apparel and footwear factories studied encompass the limited standardization of tasks linked with difficulties in material handling, and production volumes. Costs and the lack of support for financing innovation (with the need to fully rely on own resources) are other factors which can curb technological upgrading and automation. The business strategy of the factories studied, with niche, high-end goods often marketed as handmade and produced in smaller batches, was identified as another impediment to automation.

Although COVID-19 significantly impacted businesses, interviews did not suggest a link to the factories’ approach to technological upgrading.

In all factories, technological upgrading has been a gradual and fragmented process, and one in which new equipment is purchased and installed in moments of production expansion, to meet increasing demand. As such, technological upgrading and increasing automation have not been accompanied by worker layoffs. Although, by definition, automation substitutes labour input, displaced workers have been shifted to new tasks. It seems to be consensus that, to the extent that automation and the acquisition of modern machines strengthen the factory’s competitiveness and augments its productive capacity, it protects employment in the medium and long run. In sum, to date, the expansion of demand and production capacity has more than compensated the expected labour substitution effect of automation.

We have outlined two results associated to this “expansion of production through technological upgrading” strategy in terms of gender. First, the absence of labour-saving impacts means that there has been no “negative defeminization”, i.e., no defeminization of the workforce brought about by women being laid-off proportionally more than men at the factory level. Second, technological upgrading and automation have led to shifts in the composition/profile of the workforce, with reskilling, upskilling, deskilling and multiskilling, that could eventually have gender composition effects. On the one hand, deskilling and the fewer requirements associated to physical strength could lead to more women in traditionally male operations, like cutting, although this is not currently evident. On the other hand, the greater need for engineers and specialized skills has opened space for women in management positions, and many of them are team leaders in the production line.

However, even though workers are moved across the factory floor with the introduction of new equipment, leading to multitasking, some key operations, such as in sewing, remain labour-intensive and require manual expertise. This also has implications for the gender composition of the workforce, with the likely maintenance of a feminized workforce to the extent that sewing has historically been carried out largely by women workers.

Indeed, we have not found evidence of a change in gender segregation patterns, even if the two apparel factories stated that there are no gender limitations in the hiring and placement of works across tasks, with the potential exception of tasks which require physical strength. This is similar to the outcome of interviews with footwear manufacturers. Persistent gender segregation may be linked to stereotypes as well as to skills and experiences and this may have persisted with new technologies due to a legacy effect (workers remaining in the same task after technological upgrading).

An important dimension of work quality, working hours have been largely unaffected by technological upgrading. In Factories B and D, some automated machinery requires workers to operate 24 hours, but workers in other operations have regular working hours. Also, the persistence of long working hours and frequent overtime may disadvantage women. Moreover, and importantly, there could be impacts in terms of work intensity and pace of work which are worth exploring.

Finally, there are two important methodological caveats which must be kept in mind while considering these research findings. First, although interviewees were assured that interview discussions would remain confidential, that workers were selected by management and interviews carried out at the workplace may have affected answers. In addition, the findings from the case studies are not generalizable. The goal of this research project was to better understand what is happening in factory floors, i.e. to improve our understanding of how processes of technological upgrading, particularly automation, interact with local social structures and institutional systems, particularly as it relates to gender dimensions, in the apparel and footwear industries via case studies. Our findings reflect the experiences of four factories (and firms) which were selected specifically for being at the forefront of technological upgrading and automation.

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