The Impact of Technological Change in the Textile and Garment Sector on Sustainable Development in Asia

SECTOR NETWORK
Assets for Asia

Sustainable Economic Development in Asia

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Discussion Paper

Commissioned by

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Imprint

Published by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Sector Network Assets for Asia (Advanced Social and Sustainable Economic and Technical Services for Asia)

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Design and Layout
FINE GERMAN DESIGN, Frankfurt

Photo credits
Cover: © GIZ / Sabrina Asche
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November 2019

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3D	three dimensional
4IR	fourth industrial revolution
AI	artificial intelligence
ASEAN	Association of Southeast Asian Nations
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit
CAD	computer aided design
CAM	computer aided manufacturing
CEO	chief executive officer
CPO	chief purchasing officer
EBA	Everything but Arms
EBIT	earnings before interest and taxes
EU	European Union
EBA	Everything but Arms
GDP	gross domestic product
GIZ	Gesellschaft fuer internationale Zusammenarbeit GmbH
GMAC	Garment Manufacturers Association of Cambodia
GSP	generalized system of preferences
GTF	garment, textile and footwear
HS	harmonized system
I4.0	industry 4.0
ILO	International Labor Organization
IoT	internet of things
IT	information technology
LDC	least developed country
NGO	non-government organization
NIR	near infrared
OSH	occupational safety and health
PET	polyethylene terephthalate
R&D	research and development
RFID	radio frequency identification
RoI	return on investment
SG&A	selling, general and administrative (expenses)
SKU	stock keeping unit
STEM	science, technology, engineering and mathematics
TLCF	textiles, leather, clothing and footwear
TVET	technical and vocational education and training
UK	United Kingdom
UN	United Nations
US	United States
ZDHC	Zero Discharge of Hazardous Chemicals

Executive Summary: Changes Ahead for the Garment and Textile Sector

The garment, textile and footwear sector is vast, valued at $ 1.7 trillion per year in 2017, and deeply dependent on global supply chains.[1] These global supply chains often, though not always, have significant production bases in developing countries in Asia and destination markets in Europe and North America. Supply chains start with the production of raw materials such as cotton, polyester and other natural and synthetic fabrics. They include production, retailing, and even reuse/recycling. They include logistics which move inputs and products from point to point. Within any one of these areas, there are a wide array of participants. For example, retailing includes everything from single storefront retailers in developing countries to large multinationals, and from traditional retailing to online selling that uses artificial intelligence (AI) to match customers with garments. The sector covers a wide range of products, from leather shoes to knitted sweaters.

The textile and garment sector is changing. From sourcing to production to retailing, the business models and value chains that characterize the modern garment and textiles sector are transforming. In McKinsey's 2019 report "The State of Fashion," the #1 word executives used to describe the industry was "changing", cited by more than one in three executives in the sector.[2] That the sector is changing is not up for debate. However, there is less consensus on exactly how the sector will change, how quickly it will happen, what technologies will drive changes, and what the implications of these changes will be.

One of the most important drivers of change is digital and automated technology. The garment and textile sector is undergoing two closely-related technological transitions:

1. The mass adoption by existing factories of mature technologies that automate part of the production process, driven by changes in the relative costs of capital and labor. Technologies in this group include computer aided design (CAD) software, automatic spreaders, automatic cutters, automatic and semi-automatic sewing machines, automatic hanger systems, conveyor belts, automatic ironing and automatic knitting machines.
2. The structural transformation of garments and textile production, driven by new technologies that revolutionize how, when, and where garments and textiles are made. Technologies with the potential to drive this structural transformation include artificial intelligence, advanced automated manufacturing, 3D printing, blockchain, wearables, nanotechnology and body scanning.

These two transformations are deeply interconnected. Both depend on computers being integrated into production and elsewhere in the value chain. Yet there are huge differences in the degree of sophistication. The Tianyuan Garment factory in the United States (US), which uses Sewbots to produce millions of t-shirts in a highly automated facility, is a technological change of a different degree than the many factories in Asia introducing automatic cutters and bar tack machines into their existing production process.

New technologies have sparked fears of mass unemployment in developing countries in Asia. According to a 2016 study by the International Labor Organization (ILO), a significant majority of textile, clothing and footwear jobs in the Association of Southeast Asian Nations (ASEAN) are at "high risk of automation," which the study defines as areas where automation is technically possible. The study found that 64 % of jobs were "at risk" in Indonesia, while in Vietnam the figure was 86 % and in Cambodia 88 %.[3] These figures reflect a trend in the industry that automation is most likely for simple tasks and garments, whose production is concentrated in countries such as Cambodia.

However, other studies have found that the share of jobs at risk of automation is much lower. A 2017 study by McKinsey took a different approach, looking at work hours instead of jobs, and found that 16 % of current work activity hours in China could be automated by 2030.[4] Even in a scenario of rapid transition, they found that 31 % of work activity hours would be automated by 2030.[5] While there is significant variation in these estimates, it seems highly likely that employment opportunities in the garment sector will not keep growing at the same rate that they have in previous years. The risk of 'jobless' growth in the garment sector is significant.

Some industry sources have pushed back against these dire predictions of job losses, noting that such dramatic changes are not economic or part of their sourcing plans. For example, the Chief

Executive Officer (CEO) of Crystal Group, the world's largest clothing maker, said in a 2018 interview that high tech sewing robots won't replace many of their workers in the near term because "they still can't beat cheap human labor on cost." [6] There are also significant costs associated with investing in new, automated machines. Some authors have noted this, arguing that while the high rates of job loss from automation are technically feasible, they are not necessarily economically feasible. [7] Because of these costs, they argue that automation will proceed at a much more moderate pace.

While there is disagreement about the effect of automation on employment numbers, there is no doubt that future jobs in Asia's garment sector will look much different than present day jobs. As factories become more automated and greater interaction with machines is required, the skill sets needed by employers will change. Demand for workers with knowledge of computers and digital machines will increase, while demand for manual sewing skills will decrease. There is a risk that automation could bifurcate the workforce, with more skilled and technologically savvy workers benefitting while other workers are relegated to unskilled jobs operating machines that have made their former skill set redundant.

Nearshoring is already gaining in importance, with reshoring also an option for some high-value items. According to a 2019 McKinsey survey of executives, 60 percent of apparel procurement executives expect that over 20 percent of their sourcing volume will be from nearshore by 2025. [8] This is still a fairly small portion of overall production, but indicates support for the overall trend of reshoring and diversification away from reliance on only low-wage Asian producers. While reshoring remains expensive, it is beginning to become competitive in certain cases. However, the same report by McKinsey argued that despite technological progress, "not even the rapid adoption of automation is likely to prompt the largescale return of apparel manufacturing to American shores." [9]

Many industry experts believe that a multispeed sourcing strategy will prevail for most brands. The multi speed sourcing strategy involves continued sourcing from traditional, low-cost producers, which according to McKinsey will "continue to play a big role" in sourcing strategies for many brands. These facilities have significant room for productivity improvements, though are already reaping some benefits from investments in technology. These will be complemented by increased production in nearby countries, often referred to as 'nearshoring' as well as production of select, higher-value items in destination countries, often called 'reshoring'. An executive of US brand Underarmour outlined a future for the industry in this way: "high-end, quick-turnover products will be produced in (semi) automated plants in the US and other developed markets, while longer lead-time commodity products will be produced in low-cost countries, where technology will support, not replace, the workforce." [10] Brands making sourcing decisions will face an increasingly complex landscape, with more highly automated factories using mostly 4th Industrial Revolution technology in destination markets both competing with and complementing factories in Asia using less sophisticated technology.

Technology will bring a number of benefits for workers, but also introduce some new challenges. One of the most likely positive effects is improved occupational health and safety. Removing workers from manual processes, such as fabric cutting and dyeing, reduces interaction with dangerous processes and substances, providing significant occupational safety and health (OSH) benefits. Likewise the productivity gains from automation should help improve wages for at least a part of the garment, textile and footwear (GTF) workforce. This is especially likely for workers who will use technology in a complementary role, such as sewers who move from a manual line to one with an automated hanger system. However, automation may reduce the bargaining power of workers in collective bargaining, as employers increasingly weigh the costs of labor versus automation in a bid to stay competitive. This could have a negative effect on the ability of workers to negotiate for higher incomes and benefits, a phenomenon already experienced in sectors such as automotive.

New technologies hold major promise to improve environmental sustainability. Many technologies are enabling more efficient production, decreasing wastage and defect rates. Water saving and water recycling technologies are being introduced at multiple points in the production process, including dying and washing. Numerous new technologies are being developed to enable recycling. However, there are major forces that have the potential to counteract the improved environmental sustainability that these technologies can bring. Notably, brands pushing for greater sales and growth from major Asian markets will both contribute to sector growth, and therefore increase the sector's environmental impact.

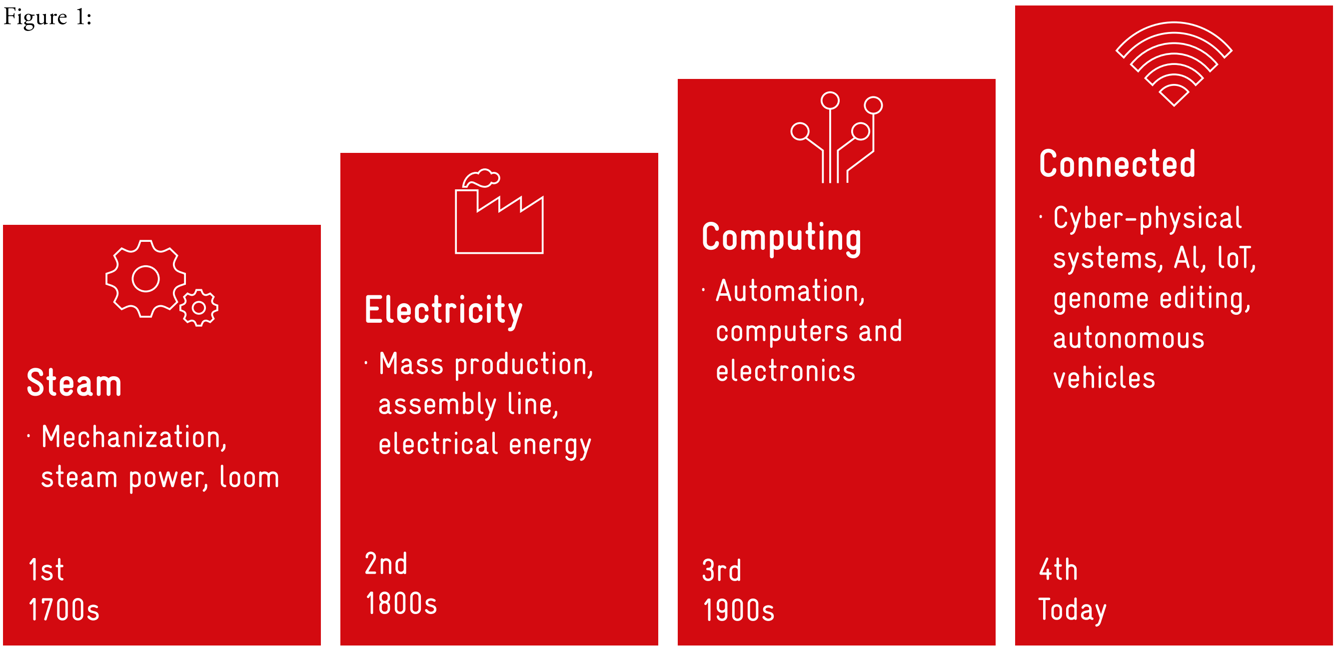
Chapter 1. Technology in the GTF Sector: The State of Play in 2019

Technology is changing the GTF sector quickly, and raising fears of mass unemployment in some developing countries in Asia. According to a 2016 study by the ILO, a significant majority of textile, clothing and footwear jobs in ASEAN are at "high risk of automation." The study found that 64 % of jobs were at risk in Indonesia, while in Vietnam the figure was 86 % and in Cambodia 88 %.[11] Other studies found lower levels of potential risk. A 2017 study by McKinsey found that 16 % of current work activity hours in China could be automated by 2030.[12] Even in a scenario of rapid transition, they found that 31 % of work activity hours would be automated by 2030.[13] Regardless of the estimates used, the GTF sector in Asia is facing the potential loss of millions of jobs, and significant changes in how garments are produced.

In comparison with many other manufacturing sectors, the GTF sector has lagged behind in the adoption of automated processes in manufacturing. This is partly because the materials used in garments, which are soft and flexible, are difficult for machines to handle. Because of this, the sector has remained relatively labor intensive. With labor costs responsible for a significant share of total costs in GTF manufacturing, production has moved in recent decades from Western destination markets to lower wage countries in Asia, first China and then Cambodia, Bangladesh, Vietnam, Pakistan and Myanmar, among others. Until recently, the GTF sector in Asia had yet to see the effects of the third industrial revolution, when automation, electronics and basic computing revolutionized manufacturing processes (see Figure 1).

The GTF sector is poised to experience significant disruption with the introduction of new, cutting edge technologies and the mass adoption of a range of mature automated technologies. These include fourth industrial revolution (4IR) technologies such as AI, blockchain, 3D printing, wearable technology, and the digitalization technologies that enable the physical-digital-physical loop that characterizes 4IR manufacturing.[14] These technological advances will help the GTF sector develop automation that many other manufacturing sectors achieved after the third industrial revolution, and could fundamentally change the way that supply chains and GTF production work. Other technologies have the potential to significantly increase the efficiency of the sector, which in some countries still depends heavily on labor-intensive production.

Figure 1:



Source
PWC, "Are you ready for tomorrow – no matter what tomorrow brings?" https://www.pwc.com/us/en/library/4ir-ready.html

Chapter 2. Methodology and Approach

Technological change is happening across the GTF sector broadly, so we limit the breadth of this paper to focus on changes that are most important for countries in Asia. The reason for this focus is because the purpose of the paper is to inform development cooperation policy of Gesellschaft fuer internationale Zusammenarbeit (GIZ) GmbH, which works in many large GTF manufacturing counties in Asia. Beyond the geographical restriction, we propose a few other criteria to focus the attention of the study, which are necessary because of scope of the sector and the large number of new technologies which may affect it.

First, we focus on technologies that will have a major impact on the sector in the next ten years. Technologies are at various stages of their life cycle. Some, like automatic knitting machines, are already being deployed en masse and disrupting the GTF industry in Asia. Others are in early stages of development, and while they have the potential to change the garment industry significantly, are still years or even decades away from widespread adopted. Because the focus of this report is on actionable recommendations for the near to medium-term, we focus on technologies that will have the most significant impact in the next decade, as is projected by industry experts and academics.

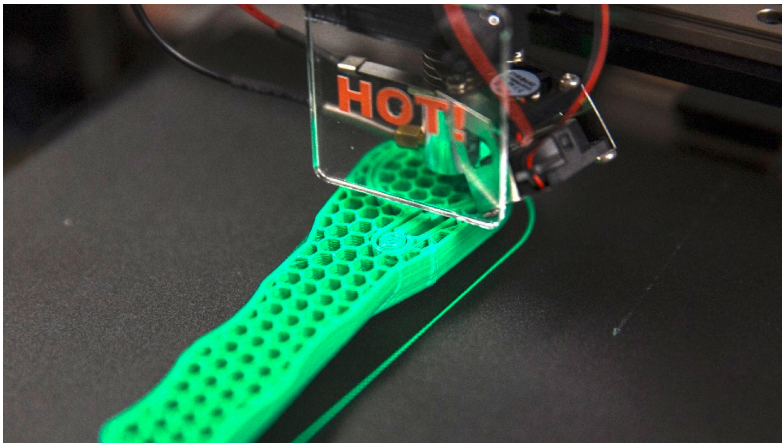
Second, we focus on technologies that affect the parts of the value chain in Asian countries where GIZ works. This includes not just the in-factory technologies that will increase automation and reduce demand for labor. It also covers parts of the supply chain that can bolster the environmental, social, labor and economic stability of the sector in Asia, such as the use of blockchain to promote supply chain transparency. Some technologies that will affect the sector will primarily have an effect on final markets, especially retailing of clothes. We will review some of these technologies, especially when they affect supply chains, but will not focus on them in this report.

Lastly, we focus on technologies that will affect the mid-market and value segments of the GTF sector. The high end of the market is moving towards advanced, integrated, mass customized garments, and there are numerous technologies in development that are driving this, including body scanning technology, wearables, and nanotechnology. While these technologies are of significant appeal to consumers, they will likely be out of reach for the vast majority of the world's population over the next decade. There are some efforts to bring these to larger audiences, for example body scanning software for smart phones, however this seems aimed to better match customers to existing sizes instead of true mass customization. As such, these technologies will not be a major focus of the paper given the comparatively small size of their potential near-term markets. Instead, the report will focus on the mid-market and value segments of the sector, where Asian countries have and will likely continue to play an important role.

This report is based on a literature review, industry interviews, and experiences of both the author and GIZ in the sector. The literature review covered a wide range of sources from industry experts, consulting companies, international organizations, government, non-government organizations (NGOs) and others. Because the research focuses on recent trends, almost all of the literature reviewed is from the last five years. A large number of news sources and industry periodicals were also reviewed, as these sources provide up-to-date information on developments that may not yet be included in other publications. Interviews were conducted with international brands, factories, international organizations, and other stakeholders. Data on trade of machinery for the garment sector is from the United Nation's (UN) Comtrade database, with the analysis done by the author.

Chapter 3. Technology in the GTF Sector

In this section, we look at both 'cutting edge technologies' as well as more mature 'efficiency driving technologies' that are experiencing mass adoption. There are a wide range of technologies that are affecting the sector, they are all in different places in regards to their levels of maturity and adoption. Some, such as Sewbots, have much more disruptive potential for Asian source countries in the next decade than others, such as wearables, which will have a more limited impact. Generally speaking, many of these advanced technologies are still under development or in the early stages of commercial roll-out. They are utilized by a smaller number of often exceptional companies and organizations and are not within the financial and technical reach of most garment and textile manufacturers in Asia.



A look at the future: cutting edge technologies

Advances in artificial intelligence, robotics, etc. have led to a significant number of new innovations in the GTF sector. These fourth industrial revolution technologies have the potential to reshape the sector, however many of them are in the early stages of design and roll-out. In this section we review cutting edge technologies that are in development or the early stages of commercial rollout.

3D printing

3D Printing, also referred to as additive manufacturing, involves building a three-dimensional object by adding material one layer at a time. [15] 3D printing uses plastics, liquid resins or other similar materials. The technology holds significant promise in a number of areas, including the mass customization of garments and textiles. 3D printing can also help to reduce waste in the manufacturing process, and reduce the number of materials in a garment or shoe, thereby increasing the potential for recycling in the future.

3D printed clothes have been produced by a number of high end designers, but some industry experts believe they are decades away from mass adoption.[16] Numerous high end designers are experimenting with 3D printed garments. [17] However, the technology is in the very beginning stages, and currently constrained by high costs, unsuitable materials and garments that lack functionality. 3D printed garments suffer from some significant drawbacks, including a tendency to be stiffer or less comfortable.[18]

3D printed footwear holds significantly greater promise for mass production in the decade. For most of the 2010's, 3D printing was used to reduce time and costs associated with producing prototypes. It helped produce a model before the time consuming and costly process of producing molds. However, in the last two years, 3D printed shoes (or shoes with significant 3D printed components) have hit the market. Adidas is at the forefront of 3D printed footwear, with 3D printed shoes already available in the marketplace. In partnership with 3D printing company Carbon, Adidas has launched Futurecraft 4D which has 3D printed midsoles. In 2018, the company made 100,000 pairs available and plans to ramp up production to millions in the coming years.[19] The technology has the potential for creating mass-customized midsoles, enabling creation of high performance shoes unique to each user's foot. [20] Other companies, such as New Balance, have released 3D printed shoes as well. [21]

Blockchain

A blockchain is a "single, shared, tamper-evident ledger" that requires multi-party consensus to verify transactions and prevents them from being altered once recorded. [22] The information on blockchain is not stored with a single party or at only one location but is instead distributed amongst many parties. Blockchain, as the name suggests, allows information 'blocks' to be stored in a chain, creating a single source of information about goods as they move through a supply chain. It has the potential to significantly reduce paperwork and speed up transactions.

There are many blockchain-based companies offering services applicable to the GTF sector, such as VeChain, which provides tools for supply chain management and transparency. VeChain has rolled out blockchain applications for numerous clients, including Walmart, which has launched a traceability platform for 23 products and plans to launch it for more, including fresh meat, cooking oil, vegetables and other food products. [23] The same blockchain application can be rolled out in the GTF sector, allowing traceability of products from the stage of raw materials throughout the supply chain and to the end consumer. This technology could help ensure data validity, for example by providing evidence on whether a raw material was sustainability sources or a garment produced in the contracted factory as opposed to a subcontractor.

Blockchain can also be deployed in human resources management. For example blockchain can enable the use of smart employment contracts, which are contracts that are stored using blockchain technology and therefore immutable. Blockchain could be used to help brands conduct remote audits, ensuring compliance. They could also be used by factories for attendance and production records, ensuring that workers and employers are unable to modify them after they have been agreed. [24]

Advanced automated manufacturing

More than almost any other area of technology, advances in automated manufacturing have attracted significant attention because of their potential to displace workers. For garments, sewing is generally the most labor intensive part of the production process and employs more workers than other parts of a factory. Because of the soft and flexible materials generally used in GTF production, automation and robots have historically struggled to manipulate fabrics in order to produce garments. However, new technological advances are facilitating the fusion of physical and digital worlds. Using various sensors and cameras, new machines can gather information, analyze it, and make adjustments in real time. This feedback loop has drastically changed the prospects for automated manufacturing in the GTF sector.

The 'smart factory' could revolutionize information management in GTF production. These future factories would be "completely automated, self-servicing, and self-repairing structures". They would have "real-time processing and analysis of data from web-based IoT (internet of things) devices and sensor" [25] Decision making could even be automated so that the factory's systems could automatically adjust based on the data collected by various sensors and inputs. However, while components of a smart garment factory exist, there are not yet examples of this and they will not replace current modes of production at any significant scale for the foreseeable future.

Amongst the highest profile automated sewing system are "Sewbots," produced by US-based Softwear Automation. Sewbots are a fully automated sewing line capable of producing over 2,000 different garments, including t-shirts, pillow cases, towels and shoe uppers. [26] The T-shirt work line can assemble one shirt in 2.5 minutes, reducing labor by 90 %. They are at the very early stages of commercial adoption, with the first Sewbot-equipped

Case Study: OnPoint Manufacturing

OnPoint Manufacturing is a US-based on-demand contract manufacturer of garments and textiles that exemplifies the potential of highly automated, destination country production. Onpoint is a small (approximately 50 employees) and niche producer. They brand themselves as in the business of "purchase activated apparel" because they do not produce the garment until after it is order. Each garment is customized to the measurements provided by the customer, which OnPoint says allows brands to charge a premium price because they provide customized items. The on-demand manufacturing model also allows the brands that use it to operate with no inventory, which means no discounting or liquidating stock. It also reduces waste in the production process and environmental damage from shipping, because OnPoint ships items directly to the customer. OnPoint's model is facilitated by software which allows them to "manufacture millions of unique SKU's (stock keeping units) on-demand," but with no minimum order size. They use an online portal through which brands place orders, which are then fulfilled in a highly automated factory that includes automatic cutters and a system of conveyors, all integrated into the company's central computer system.

Source: www.onpointmanufacturing.com factory in the US expected to start production in 2019.[27] At full capacity, the factory plans to produce 800,000 T-shirts daily, at a cost of 33 cents per shift. The factory notes that each shirt will have a "personnel cost" of roughly 33 cents, though it is not clear how total costs (including capital costs for the Sewbot lines) will compare with production costs in developing countries.[28] While these advances are impressive, there are still many sewing tasks that automated production lines cannot produce. While SoftWear Automation believes that within five years, they will be able to fully automate machine-made jeans and dress shirts, the CEO has publicly stated that they will "never make a bridal dress."[29] At present, Sewbots are not available outside the United States, though this may change in the future.

Amazon has recently patented a production system for "Prime Wardrobe," its attempt to enter the subscription wardrobe business. The system would integrate data on apparel ordering and manufacturing and include interfaces with textile printers, cutters and assembly/producers. The system would gain economies of scale by aggregating many orders from a large geographical area. If successful it could facilitate cost effective, on-demand customized clothing production.[30]

Artificial intelligence

AI is based on algorithms that are designed to make decisions, often using real-time data.[31] These algorithms use sensors, digital data or other remote inputs to "combine information from a variety of different sources, analyze the material instantly, and act on the insights derived from those data."[32] They are designed to be able to analyze and react, not simply implement a pre-programmed response. AI currently has a number of applications relevant to the GTF sector.

Algorithm-driven retailing are disrupting the already quickly changing business of GTF retailing. Online companies such as Stitch Fix are using algorithms to select and send personalized clothing collections to customers.[33] Customers complete an online "Style Profile" which is then run through a number of algorithms before a stylist selects a subset of the AI-determined garments to the client. Of course, Stitch Fix is not the only company using AI to help clients with styling. Levis has a "Virtual Stylist" that helps find jeans with the right fit, size and stretch.[34] AI is also being used by GTF companies to better manage inventory, and also to reduce return rates which are exceedingly high for online orders (estimates of approximately 40 %).

Artificial intelligence is also being used in machines that are being introduced into the GTF sector. For example, Hong Kong Polytechnic University has recently developed "WiseEye", an automatic fabric defect detection system. WiseEye uses cameras to capture and analyze woven fabric in real time, and artificial intelligence-drive algorithms single out abnormalities in the fabric and either record them or flag them in the factory's quality control system.[35]

Body-scanning technologies

A number of body scanning technologies, using lasers, photographs or other means, are helping create a 3D image of the body to create customized garments or ensure proper sizing of pre-made garments.[36] At present, there are over a dozen different laser body scanning technologies on the market. Other businesses, such as Nettelo, have taken a different approach and developed a smartphone application that allows users to capture body measurements on their smartphones. These measurements can then be used to sync up with garments and textiles offered by e-commerce merchants, though this has not yet been done on a large scale.[37]

Body-scanning technologies can help drive both improved mass retailing as well as mass customization. For mass retailers they can help reduce incorrect fitting and returns. This is especially important for online retailers, where returns can average between 30 % and 40 % of sales, and up to 50 % for some items such as dresses.[38] Body scanning can help reduce the costs of shipping and therefore waste. For mass customization, body scanning is a fundamental part of the process necessary to capture the body dimensions of each customer, which could then be fed into a production process. However, the effects of body scanning technology will primarily be concentrated at the retail part of the GTF sector until automated production technologies improve and reduce the costs of mass customized garments.

Wearables & nanotechnology

Nanotechnology is the manipulation of matter at a scale of less than 100 nanometers, and is used to incorporate a range of materials into garments and textiles.[39] The types of materials that can be incorporated into garments and textiles vary, but can include graphene, carbon nanotubes, clay, carbon black, metal and metal oxide.[40] These materials can give the garment or textile a range of properties, for example making it stain resistant, wrinkle-free or electrically conducive. Numerous companies have already brought nanotechnology-driven garments to market, such as Deewear (graphene sportswear), Aspen Aerogels (insulating textiles), and Nanotex (various fabrics that can repel water, resist stains, etc.).[41] Nanotechnology has also helped create anti-microbial clothing, wound dressings and bedding for the medical industry.[42] Nano Textile, an Israeli company, has developed a nano-coating for textiles that give them permanent antibacterial properties, helping to prevent infections.[43] Besides positive characteristics such as repelling water, resisting stains and providing antibacterial protection, some garments and textiles produced with nanotechnology may be significantly more durable, potentially reducing the number of garments produced and discarded.

Wearables are everyday products such as a watch, shoe, or headband that include sensors or other technology that collect data on *human activity.* Numerous wearables are already commercially available, including popular examples such as the Apple Watch and Fitbit. Many wearables are focused on health-related applications, such as monitoring physical activity or vital signs, such as a pulse.[44] Besides their health and fitness applications, wearables have also been adopted by niche users, such as the US Air Force. In conjunction with private companies, the US Air Force has developed a compression undershirt that monitors vital signs, including a tissue oxygenation sensor integrated into the garment. This wearable allows for the remote monitoring of pilots while deployed.

Sustainability-focused technologies

With over 150 billion new clothing items produced every year and 2.5 billion pounds of garments going to landfills each year, the environmental impact of the GTF sector is significant.[45] However, a number of forces are coming together to incentivize and facilitate a transition to more sustainable technologies. First, consumers, especially younger millennials, are increasingly considering sustainability and transparency in purchasing decisions. Secondly, new technologies are enabling businesses to both increase sustainability and reduce costs and waste. According to the Global Fashion Agenda's 2018 report, "enhancing resource efficiency in water, energy, and chemicals has the potential to improve a fashion company's EBIT margin up to 2-3 percentage points by 2030, as compared to the 2015 baseline."[46]

Recycling is becoming more important to the GTF sector, including production using recycled materials, design to facilitate future recycling, and technology to make recycling possible. Numerous research organizations and companies are working on various aspects of recycling in the GTF sector. For example, Adidas has crafted a running shoe, called the Futurecraft.Loop, whose upper is made entirely of "yarns and filaments reclaimed and recycled from marine plastic waste and illegal deep-sea gillnets."[47] The use of the word "loop" in the name references the move towards a circular manufacturing model where materials are repeatedly repurposed. The Hong Kong Research Institute of Textile and Apparel has developed a chemistry-driven recycling method that can separate cotton and polyester, helping recycle poly-cotton blend garments that previously were not recyclable.[48] The polymer recycling technology can "separate, decontaminate and extract polyester polymers, and cellulose from cotton, from non-reusable textiles and PET bottles and packaging," facilitating recycling of garments that was previously impossible.[49] The Textile Sorting Project is developing a tool that can separate collected garments according to fiber composition using NIR (near infrared) technology.[50] Similarly, Valvan Fibresort has developed an automatic machine that sorts garments based on their fabric content, enabling more efficient recycling of garments.[51]

Environmentally-friendly production methods are being developed to help reduce the significant environmental impact of the GTF sector.[52] In 2015, the sector is estimated to produce some 1.715 billion tons of CO2 per year, and uses some 79 billion cubic meters of water.[53] By some estimates, one fifth of the world's industrial water pollution is from the GTF sector.[54] Numerous cutting-edge technological advances may help reduce that. Biotechnology company Modern Meadow is developing lab-grown leather, creating materials through biofabrication using collagen. This significantly reduces the environmental impact associated with the traditional raising of cattle and tanning of hides. Some processes, such as finish denim, are being replaced by newer, environmentally friendly processes. For example, Levi's Project F.L.X. is one of a number of laser finishing system that prints customized, digitally-designed patterns onto jeans.[55] The system reduces waste, eliminates need for chemicals and reduces the need for labor. Xeros, a UK company, has developed nylon beads that can be used during washing, significantly reducing water consumption.[56] Tonello, in collaboration with Levi Strauss, has developed a water free finishing process called NOSTONE, which provides a similar finish to stone washing.[57]

Environmentally friendly dyeing techniques have also been developed. For example, Dyecoo has developed a technology that uses CO2 in the dying process, creating no wastewater.[58] Besides the environmental benefits, this technology gives businesses greater flexibility on where they locate dyeing facilities. They no longer need to dye only in locations with ample supplies of fresh water. Likewise, this technology also undermines the incentive to locate dyeing activities in areas with weak regulation, where costs of compliance may be lower. As well as CO2 dyeing, there are also a range of more environmentally friendly dyes coming on the market.[59] For example, a number of different groups are working on bacteria-produced dyes, which eliminates the need for chemical agents that are normally part of the dying process.[60] Indigo Mill Designs has developed a foam dying technique that reduces water and energy use by 90 %, and is being adapted by suppliers for Wrangler and Lee in both the U.S. and Mexico.[61] There is not yet industry-wide data available on the uptake rates for alternative dying processes.

Digital applications are also being deployed to help improve social sustainability in the GTF sector, through app-based workforce management. A number of digital applications have been developed to help factories with various aspects of workforce engagement. For example, Kutumbita is an app that helps factories "send alerts, handle grievances, create surveys, conduct trainings, inform about labor rights, and more", all through an application that workers can download on their phone.[62] The app aims to encourage greater information sharing between workers and managers, while keeping interactions efficient and organized. It also helps create additional transparency for brands that source from factories. Another example is Sustify, which uses a digital application to provide customized and measurable trainings to workers on social and environmental standards.[63] The trainings are designed to be interactive and gamified, helping increase engagement and retention.

Efficiency-driving technologies experiencing mass adoption

While many cutting edge technologies are still undergoing testing or have only recently been launched in commercial pilot projects, a number of older, computer aided technologies are being adopted on a large scale. Over the next decade, these technologies will continue to change the garment sector through increasing productivity and efficiency and changing the types of skills needed for producing garments, textiles and footwear.

The various technologies in this section sometimes exist on their own, but often are integrated with other technologies in the produc-

tion process. For example, computer aided design software can be directly integrated with automatic fabric spreaders and cutters. For example, Gerber's CAD software, ACCUMARK, can generate a bar code containing the information on the design. This bar code is scanned at an automatic spreader which retrieves the information and completes the spread. The spreader then prints another barcode, which is scanned at the automatic cutter to retrieve the cutting file.[64] The integration of computers into the manufacturing process is called computer aided manufacturing (CAM), and together are known as CAD/CAM. This type of integration is different from 4th Industrial Revolution technologies, but is still a significant step towards increased factory sophistication. Many of the efficiency-driving technologies are the building blocks and forerunners of the automated 'smart factories' of the future.

Computer-aided design

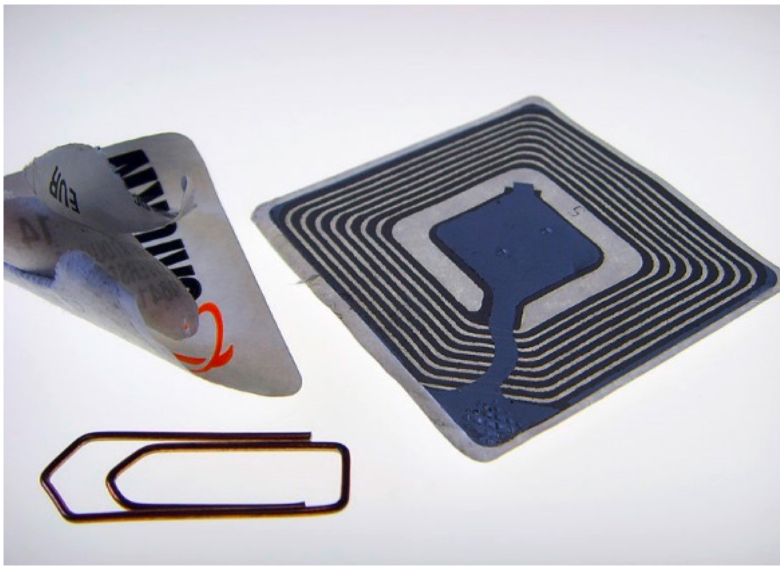
Computer-aided design software is used by brands and designers to develop digital textile and garments designs for production. The vast majority of brands and designers use CAD, which is fundamental for the increased efficiency that comes through CAM. Computer files can be sent from buyer to factory instantly, and designs then printed on a plotter printer or sent directly to spreading and cutting equipment or knitting machines. Increasingly, factories in Asia are employing staff that can use CAD software, developing designs in-house.

Automatic fabric spreader

Automatic fabric spreaders use digital instructions from either a direct input or CAD file, combined with sensors, to guide the spreading process. Fabric spreading is the process of unwinding rolls of fabric onto large tables in preparation for cutting. Manual spreading can involve 2–4 workers, with results being less consistent and dependent on the skill of the worker. Automatic spreading can increase speed and accuracy of the spread while reducing the labor required. Automatic spreading is often integrated with automatic cutting.

Automatic fabric cutter

Automatic fabric cutters are amongst the most popular technological innovations being adopted in garment factories, because of their improved efficiency, accuracy, and safety when compared with manual cutting. Manual fabric cutting requires significant skill, with some operations taking over a year to master. Mistakes in the cutting room can also be expensive, leading to defective pieces and in the worst case, the complete loss of the fabric. Because manual cutting also involves blades, it presents occupational safety and health risks for workers. Automatic cutters can lead to significant OSH improvements by eliminating the need for workers to be in close proximity with a blade. Automatic cutters reduce the time needed to cut fabric, and can reduce floor space dedicated to cutting by 20–50 %.[65] In some case studies, the switch from manual to automatic cutting and spreading together have reduced the labor required in the cutting room by nearly 85 %, though the cutting room generally accounts for a small share of labor in most factories. According to one Cambodian factory, the return on investment (ROI) on an automatic cutter is approximately 2 years. They noted that it reduced the number of workers required for cutting by 75 %.



Radio frequency identification

Radio frequency identification (RFID) is a technology that uses radio frequencies, tags, and computer systems to track the movement of items both in production and retailing. RFID allows real-time data collection and monitoring, increasing the ability for management to monitor and adjust production processes to maximize efficiency. RFID has numerous benefits over manual or bar code systems. One of the biggest benefits is that RFID can be read without line of site between the reader and the RFID chip, unlike a bar code system. Multiple RFID tags can be read at once, and they can store significantly more information than a bar code.[66]

RFID technology is not new – the technology has its roots in the World War II era, with early working prototypes from the 1970s. In the GTF sector, some early adopters of the technology have been using it in the manufacturing process for over a decade.[67] However, many garment factories in the region have not adopted RFID in their businesses, and continue to use other means of tracking in their factories.

Both technological advancements and the big data revolution that is a part of Industry 4.0 (I4.0) are increasing the incentives for the GTF sector to adopt RFID. Recent developments in "microelectronics and data processing have enabled the use of less expensive and smaller components," facilitating RFID adoption in garment sector.[68] RFID nano tags, which are so small that they can be fixed inside the product itself, are also driving adoption of the technology.[69] At the same time, automation in other parts of the garment production process have increased possibilities for capturing and integrating data on operations, increasing the benefits of using RFID to track items during the production process.

Automated hanger systems

Automatic hanger systems carry garment pieces through the sewing process automatically, using sensors to determine when to move items and collecting data on throughput. These hanger systems can be beneficial for workers, increasing their productivity and reducing some motions that can, when performed repeatedly, lead to workplace injuries. They allow management to monitor production in real-time, making adjustments when necessary.

Hanger systems, according to one factory, increased the efficiency of the sewing line by 15 %, and had a return on investment of under two years.

Automatic knitting machines

Automatic knitting machines use computerized patterns to produce knitted garments with a fraction of the labor force required for manual production. Automatic knitting machines have been around for over three decades, with models introduced as early as 1987.[70] They significantly reduce waste and labor input, as one person can operate numerous automatic knitting machines.

Automatic and semi-automatic sewing machines

A wide range of automatic and semi-automatic sewing machines are being introduced by garment factories to replace completely manual sewing. There are many different types of sews, and therefore a wide range of automatic sewing machines, including but not limited to automatic single needle lock stitch, double needle lock stitch, over lock, flat lock, button attach, button hole, bar tack, snap button, blind stitch, velcro attach, pocket welting, label attach, and chain stitch. Often, a single machine has a single purpose and cannot be easily interchanged with a machine designed to perform a different job. These automatic machines significantly increase accuracy of sews, resulting in increases in overall sewing line productivity.

Because sewing is generally the most labor-intensive step of garment and textile manufacturing, automation in this area can have an especially significant effect on employment. Many of the automatic sewing machines eliminate the need for manual sewing skills, but do require operators to correctly position materials before the machine executes the sew. However, this often requires less skill than manually sewing the garment. There is a significant risk that many semi-skilled or skilled sewing workers will be replaced by machines and will be forced to take unskilled jobs operating automatic machines, potentially at lower levels of pay.

Automatic ironing machines

Automatic ironing machines are used during finishing for pants, shirts, knitwear and other garments. These machines often have a pre-formed mold over which garments are placed, and then steamed, removing the need for a flat iron. While more efficient, automatic ironing machines are not as versatile as flat ironing.

Automatic screen printing machines

Automatic screen printing machines can automatically print designs onto garments, removing the need for manual printing and reducing worker contact with hazardous materials. Workers are still needed to operate automatic screen printing machines, mostly to correctly position garments on the machine. One factory that invested in automatic screen printing in 2017 noted that it increased hourly throughput by 50 % when compared with manual screen printing.

Other automated equipment

A wide range of other automated equipment may be present in garment and textile factories including but not limited to:

- Water efficient industrial washing machines
- Automatic textile dying machines
- Automatic, energy efficient dryers.
- Water recycling
- Digital textile printing.[71]

Chapter 4. The State of Technological Adoption in Asia

Though there is limited information available on the state of technological adoption in the GTF sector in Asia, the information we have suggests that factories are adopting new technologies quickly, although from a low base. Government statistics tend not to go into sufficient detail to gain any insights about levels of technology at the business level. Likewise, generic enterprise surveys (such as the World Bank Enterprise Survey) do not contain sufficient detail to isolate technological adoption in the GTF sector.[72] The lack of country level data combined with the rapid changes in the industry make it difficult to make a direct comparison of the state of technological adaption. However, there are a small number of country-specific studies available, which generally show low levels of technological investment, but also growing investment in new technologies.

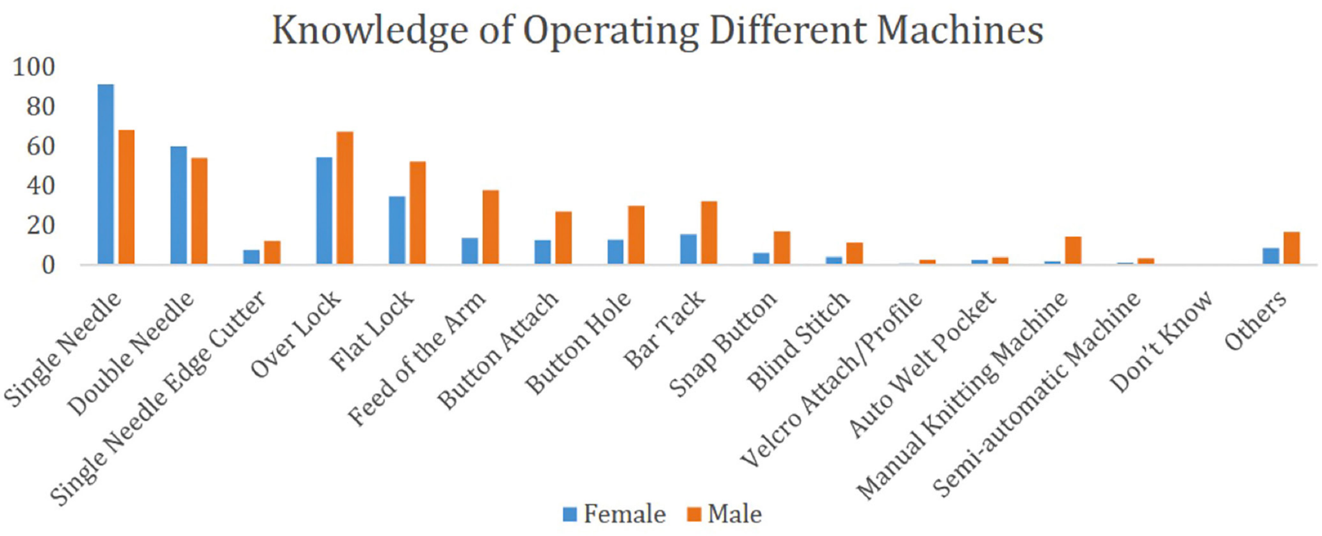
Bangladesh

The GTF sector is one of the most important sectors in the economy, and a vital source of jobs. It is responsible for 81 % of the country's exports and 20 % of gross domestic product (GDP), making it the world's second largest garment exporting country. Bangladesh focuses especially on lower value added products. The sector has grown significantly in Bangladesh in large part because of the country's abundant labor and comparatively low wages. In Dec. 2018, Bangladesh's minimum wages were increased, with the lowest now set at 8,000 taka per month (about $ 94.63). However, automation and technological advancement have raised questions about the future of this vital sector in Bangladesh.

The limited research on the level of automation in Bangladesh shows that only about 20 % of businesses have "advanced" technologies. 41 % of enterprises have 'moderately better' technologies.[73] However, there was a significant difference in technology levels when broken down by business size. Large businesses were much more likely (47 %) to have an 'advanced' level of technology than small enterprises, none of which reported having an 'advanced level' of technology. 60 % of small enterprises reported having low or moderate levels of technology. while adoption of new technologies is concentrated at large factories. This suggests that the trend towards consolidation, with fewer highly efficient factories, is likely to continue, due in part to the greater ability of big suppliers to access capital and invest in new machines, at least in a part of their overall operation.

The research also found that automation "reduced the female workers' participation ratio in the garment sector". The share of women in the sector was 60.8 % in 2016, down from 64 % in 2015. According to Khondaker Golam Moazzem, research director of the Centre for Policy Dialogue, this decrease is due to factory owners that "think female workers are not able to handle modern machines properly."[74] The study found that while a greater percentage of women had knowledge on operating single and double needle sewing machines, the share of women with knowledge of almost all other types of semi-automatic and automatic sewing machines was lower than the share of men with that same knowledge.[75]

That women had less knowledge of semi-automatic and automatic machines demonstrates the potential gender-related challenges associated with automation. The study findings are worrisome because they show that, at least in the early stages of automation, gender stereotypes that some observers have feared would negatively impact women are being borne out. However, the finding is also surprising given that the operation of many of the automated machines examined (such as button hole or bar tack machines) involve low-skill, repetitive tasks where an operator



Source
https://www.textiletoday.com.bd/china-building-tech-intensive-textile-industry-leaving-low-value-business/

positions items for the machine to perform its pre-programmed task. These are not the skilled jobs of I4.0, and as such, it is problematic that factory owners doubt the capacity of women work in these roles.

Pakistan

Much like Bangladesh, Pakistan's GTF sector (including leather) plays an outsize role in the country's economy. According to the World Bank, cotton manufactures account for 55 % of the country's merchandise exports over the past decade. [76] Notably, Pakistan's exports have remained heavily concentrated "in a small set of products – dominated by textiles – with very little export growth due to entry into new product markets." [77] The ILO estimated that the country's garment sector employed 4.4 million workers, as of 2019. [78]

Despite its importance, levels of technological adoption in Pakistan are low. A recent World Bank Report found that "while there are some large, technologically advanced firms in this sector, the average firm in the textile industry is still using 30-year-old technology." [79] According to Pakistani firms, the lack of technological upgrading is a governance issue. The same World Bank report found that "textile firms complain that they do not buy expensive modern machinery due to policy uncertainty in the sector" [80] This is despite the duty on textile machinery already being at zero, though there are duties on spare parts. [81] Data on growth of imports of capital machinery shows that Pakistan has lagged behind other countries, especially Bangladesh, and the value of these machinery imports are significantly lower on a per-worker basis. The government's approach to addressing this challenge is not clear, with the World Bank arguing that "there is no consistent strategy for promoting the shift of existing clusters toward higher value-added products." [82]

China

China is the world's leading exporter of textiles, and has well developed value chains with many Tier 2 and 3 suppliers. China's market share of garment and textile exports was 38.6 % in 2015, though that fell to 35.8 % in 2016 and continues to fall. However, this export share is still nearly triple the next largest competitor. China is also a major producer of fabrics, fibers, and industrial machinery for garment and textile production. For example, China is the world's largest producer of commodity fibers, with a market share of approximately 50 %, and therefore a central source of materials for the global textile and clothing industry. [83] In some segments of GTF production, China is an unrivaled leader, for example in the fields of outdoor, functional clothing, and technical textiles. [84]

Businesses in China have been investing heavily in technology in recent years, in part to retain their competitiveness in the face of quickly growing wages. Wages in China have more than doubled since 2010, and are significantly higher than other major garment producing countries. According to the Economist, "the average factory worker in China earns $ 27.50 per day, compared with $ 8.60 in Indonesia and $ 6.70 in Vietnam." [85] This has forced Chinese businesses to invest in machinery and automation to increase workplace productivity. Notably, within the last 15 years, 90 % of all new investment in textile machinery has been in Asia, and China has been the "dominant investor absorbing by far the bulk of this investment (around 30 %–70 % of global investment depending on the textile machinery segment." [86] As the chart above demonstrates, China's investment in textiles and apparel has continued to grow, with growth rates consistently in the double digits and peaking at 68 % in 2011. *Research on the drivers of automation suggest that in China, investment has been driven primarily by voluntary labor turnover.* One study found that "voluntary labor turnover was positively correlated with robot adoption, while involuntary turnover was not" which this authors note suggested that "turnover was a cause, not a consequence of robot adoption." [87] This is notable because it suggests that automation is used to substitute when labor is not available, instead of displacing workers.

China is a leading investor in robotics and automation, however some sources suggest that because of the sheer size of China's economy, the share of factories with automation will remain moderate. China is "one of the leading importers of robots used for such automation" [88] In 2017 China installed 138,000 industrial robots, up 59 % and more than America and Europe combined.[89] It is also a major producer of automated machinery. However, McKinsey found that China's actual adoption of automation is expected to reach only 13 percent by 2025, in an "earliest scenario" modeled. [90] However, it is not clear if this metric refers the number of factories, or whether they are full or partially automated, or if it measures automation in another way.

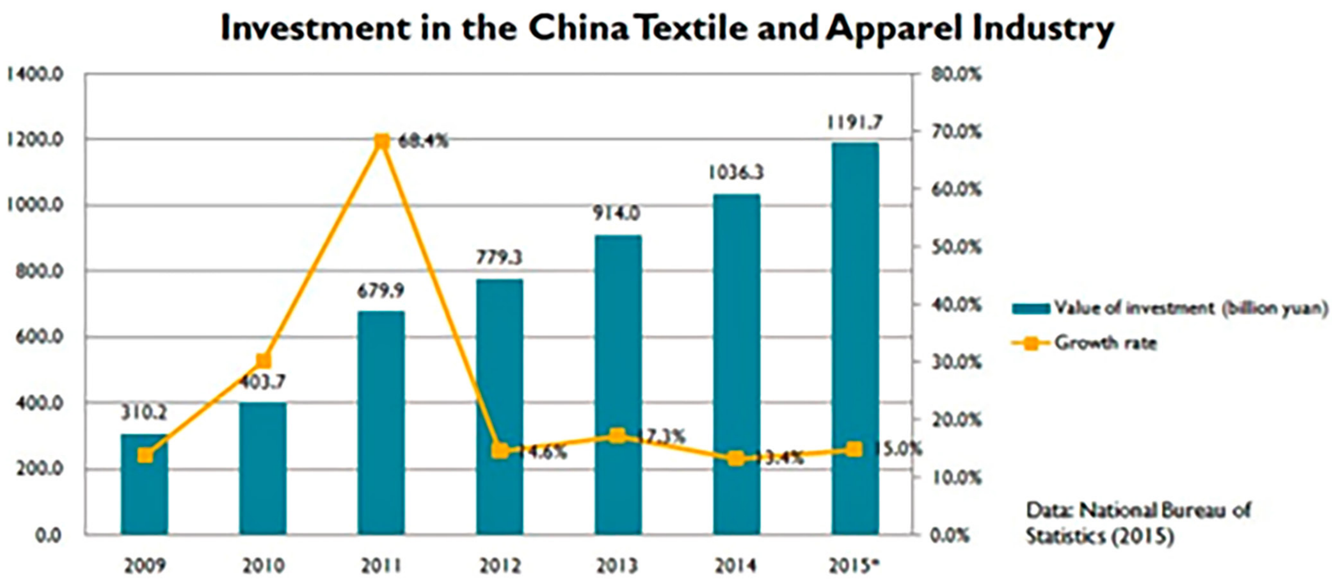
Despite significant investment, the GTF sector in China still faces challenges. Rates of investment in research and development (R&D) are low. One study found that R&D levels were below 1 % of revenue, though the "value of R&D expenditure and R&D personnel grew at an average annual rate of 26 % and 33 % from 2006 to 2011." [91] A 2015 study noted that while some Chinese factories are advancing, many factories still use dated methods. For example, clothing design is "still mostly done on paper samples," which makes product development cycles long. "China-made clothing needed 10 weeks to reach the market, whereas the world's average cycle is just 2 weeks." [92]

Vietnam

Vietnam is one of the largest and most quickly growing exports of garments, textiles and footwear in the world. Total exports of "fabric and clothing" were $ 30.49 billion in 2018, an increase of 16.4 % from 2017. The primary market was the US, which received $13.7 billion of imports from Vietnam, approximately 45 % of the country's total GTF exports. [93] The sector has grown significantly since the US-Vietnam Bilateral Investment Treaty was signed in 2001. [94] At present there are approximately 2,000 companies engaged in GTF production in Vietnam. [95]

Technological adoption in Vietnam is not as widespread as China, but various studies have indicated that the risk of job losses is significant. A 2018 study by the Institute of Strategic and Policy Research on Industry and Trade found that "about 20 per cent of producers use high-tech equipment, especially software in product design and production management, while 70 per cent uses medium technologies, and 10 per cent uses low ones." [96] Some studies have projected that in the future, there are significant risks for jobs in Vietnam's GTF sector. A 2016 ILO report estimated that 86 % of jobs are at risk of automation by 2026. [97] Other studies have produced a broad range of estimates of technology-induced job losses in Vietnam, ranging from 10 to 70 percent. [98] One Vietnamese scholar noted that losses in Vietnam are likely to be less, because sewing, which is the most dominant stage in Vietnam, has a relatively low rate of replacement by automation (of less than 30 percent). [99]

Vietnam's GTF sector is poised to continue its significant growth, though some notable challenges remain. In 2018, the EU and Vietnam concluded a free trade agreement which gives Vietnam preferential access to the EU, potentially significantly increasing Vietnam's GTF exports to the EU. These rules also require use of fabric sourced in either the EU, South Korea or Vietnam, which could help significantly grow Vietnam's domestic fabric production. At the same time, strained trade relations between China and the US have increased interest among some buyers in sourcing from Vietnam. There are important challenges as well, with one of the biggest being the lack of domestic raw materials supply. Vietnam is not a major producer of inputs, and relies on imports for 70 % of its raw materials. [100] Much of these imports come from China. The growth also faces skills-related challenges, with mechanical engineering and automation competencies having been identified as in-demand skills.



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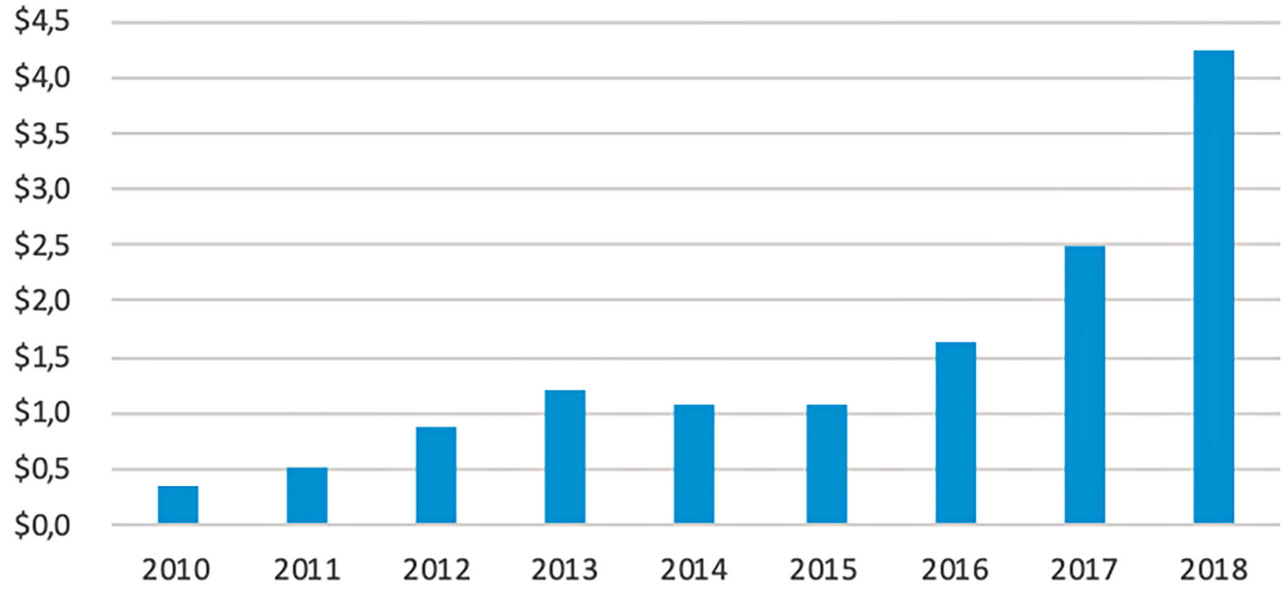
Myanmar Exports of Garments and Textiles from 2010 to 2019, in billions



Note
Data covers only gross exports, and therefore does not reflect value added or show the total value of imported components. Chart covers HS 50–63, thereby excluding footwear and certain types of bags. Source: UN Comtrade database.

Source
Own calculations using data from the UN Comtrade database (https://comtrade.un.org/data/)

Cambodia

The GTF sector has been a major driver of economic growth in Cambodia, and is one of the country's most vital economic sectors. Cambodia's GTF production accounted for 74 % of the country's total merchandise exports in 2018. [101] The value of the sector continues to grow, increasing by 17.3 % from 2017 to 2018, and by 75 % over the last five years. According to Cambodia's Ministry of Commerce, employment in the GTF sector was 660,327 at the end of 2018. [102]

Partially in response to increasing labor costs, Cambodian firms are adopting technology, though uptake remains moderated. According to one observer, only about 25 % of garment factories had introduced more sophisticated technologies, such as automated cutting machines, automated hanger systems, and automated embroidery. While the growth rate for jobs is not nearly as high as the value of output, at least one source in Cambodia contested the idea that technology will displace workers. John Cha, Executive Committee Member of Garment Manufacturers Association of Cambodia (GMAC), stated: "We have more orders. We need more workers. And we are more automated now compared to 20 years ago when everything was manual. Automation did not remove workers." [103]

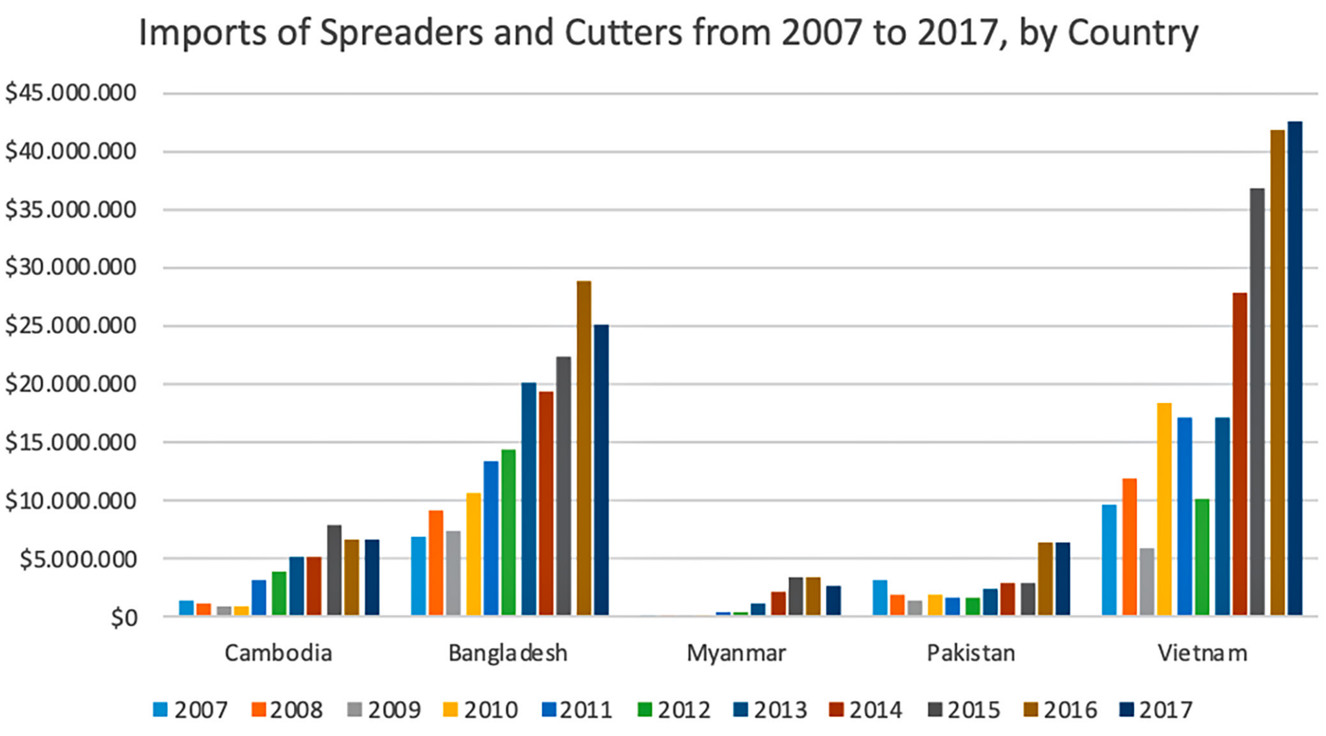
Cambodia faces a number of challenges to modernization, with some industry experts sharing a pessimistic outlook. One of the biggest barriers in Cambodia is the need for greater provision of the training to upskill their workforce. One observer noted that Cambodia "lacks both the trained workforce and infrastructure backbone to support an automated factory sector." [104] The person highlighted the electricity needs, arguing that "without a steady and uninterrupted supply of energy, many of these automated processes will be disrupted, causing multiple points of delay and unproductivity." [105] Marco Kalinna, the founder of factory assessment company Cosmos Services who has 17 years of experience working in Cambodia's garment sector, was similarly pessimistic. "Cambodia can only be competitive in those areas where labour costs are still an advantage," he said. "Mass-automation will find its place where electricity costs are affordable and where there is proximity to the markets, and Cambodia has none of these." [106] Cambodia also faces significant non-technological risks, notably the threat that the preferential Everything but Arms (EBA) trade preferences enjoyed by Cambodia may be withdrawn.

Myanmar

The garment sector is the most important manufactured export for Myanmar, and has grown significantly in the last few years. Over the last decade, garment exports have grown to $ 4.23 billion in 2018. The growth has been dramatic especially from 2016 to 2018, during which time the value of gross exports increased by more than 150 %. The garment sector is also the country's most important source of industrial jobs. As of 2018, the garment sector employed some 450,000 workers at export oriented factories. The figure would be significantly higher if domestic oriented factories, as well as producers of footwear, bags, and other textiles were included.

A forthcoming report from the ILO examined automation in Myanmar and found that the vast majority of factories are investing in some type of automation, though often for only a part of their production process. The area within factories where businesses most regularly adopted new technologies was in pre-production and cutting departments. Many factories had invested in CAD or plotter printers, while investments in automatic cutters were also fairly common. The study also surveyed more than 250 factory workers, but found that only 11 had experienced some type of technological upgrading at work. However, these figures were likely influenced by the relative youth of the sector in Myanmar. Most factories are newly established and would be unlikely to upgrade so soon after purchasing equipment at the start of factory operations. Notably, of the workers surveyed, 56 % reported using semi-automatic machines at work. Forty percent noted that they used manual machines, while only 4 % said that they used automatic machines.[107] Notably, the study suggested that skills transfer on automated machines remains limited, as factories often bring in foreign technicians for maintenance and repair.

Myanmar faces numerous challenges in automation, including a poor supply of electricity and significant skills shortages. The most regularly cited in the ILO study was with electricity – both the regular power cuts as well as inconsistent voltage. Automated machines can be vulnerable to changes in electricity, so poor supply can have a significantly greater effect on production. This is a leading reason why Myanmar has struggled to attract additional foreign investment in the sector. The other key challenge is skills. The majority of factories surveyed said that "regular maintenance of automated machines" was amongst the top three most important skills needed for continued automation. "Strong information technology (IT) and computer skills" were cited as the second most important required skill, tied with "unscheduled repair of automated machines." These skills deficits, combined with generally lower levels of productivity, are likely to make Myanmar a slower adopter of automation technologies than other countries in the region.



Source
Own calculations using data from the UN Comtrade database (https://comtrade.un.org/data/)

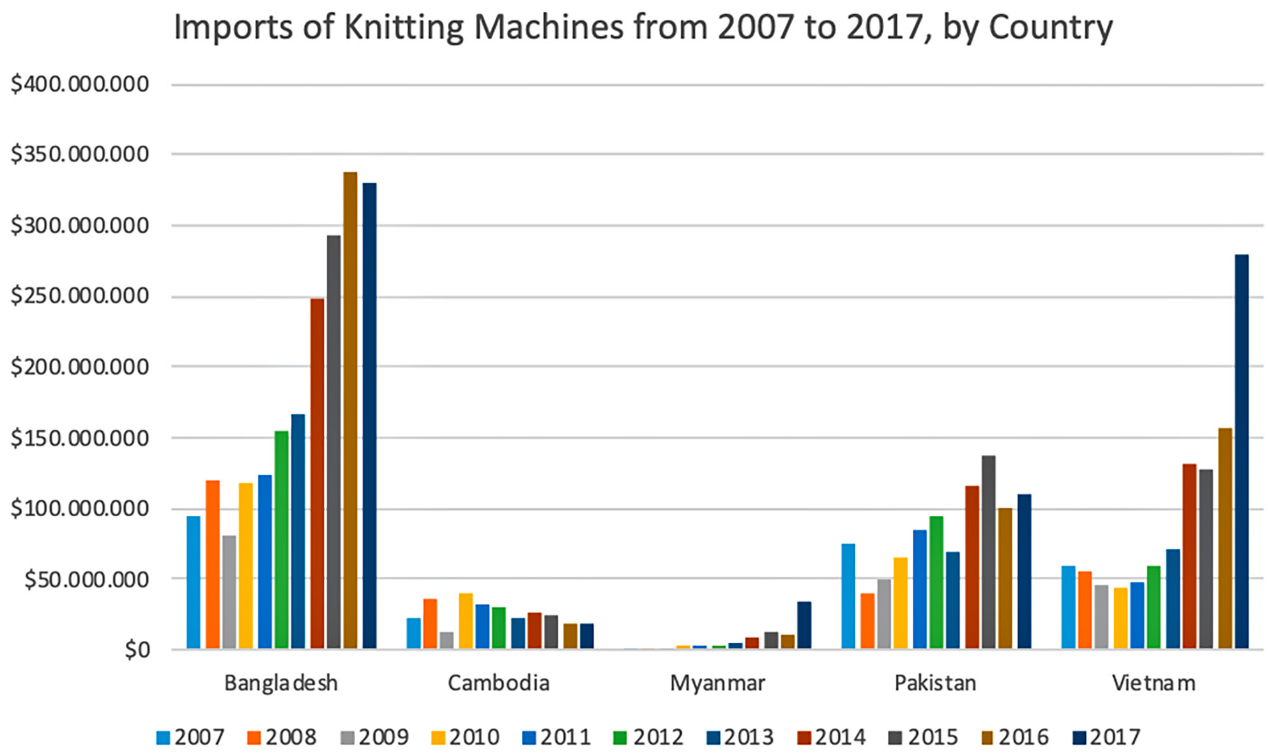
Trends in imports of garment and textiles machinery

In order to examine spending on textile and garment machinery, we use trade data on imports of spreaders and cutters (HS 845150) and knitting machines (HS 8447). We examine five countries, Bangladesh, Cambodia, Myanmar, Pakistan, and Vietnam which rely mostly on imports of machinery, not domestic supply. The trade data serves as a useful proxy for the level of investment in machinery, and as a decent proxy for the level of technological sophistication of the machinery (more advanced automatic equipment is significantly more expensive). [108] Of course, this is not a perfect approach. Other factors can influence machinery imports. For example, imports by Myanmar have increased dramatically, due to economic and political reforms in the early 2010's. At the same time, recent decreases in Cambodian imports may reflect political changes or uncertainty regarding European Union (EU) duty free market access.

In a number of major garment and textile producing countries, there has been a significant increase in imports of sector specific machinery, such as spreaders and cutters.[109] We find that exports of machinery have increased significantly. In Cambodia, imports of cutting and spreading machines have increased 360 % from 2007 to 2017, though have decreased somewhat in recent years. In Vietnam it has increased by 338 %. In Bangladesh imports have increased 266 % and in Pakistan, 104 %. In Myanmar they have increased over 3000 %, though this is largely due to the virtually non-existence of the garment sector in this country in 2007, because of the political situation.

Over that same time period, Vietnam, Bangladesh and Pakistan have also experienced significant growth in imports of knitting machines. In Vietnam, knitting machine imports have increased by 362 % from 2007 to 2017, while in Bangladesh, they have increased by 248 %. In Pakistan they have increased 49 %. In Myanmar, they have increased over 3000 % again, though due to different reasons mentioned above.

The growth rates for imports of textile and garment machinery are significantly higher than growth rates for textile and garment employment. This suggests that businesses in the GTF sector are gradually investing in new technologies, becoming more capital intensive and moving away from just a reliance on low cost labor. For example, from 2007 to 2017 the number of workers in the Bangladesh textile and garment sector increased from 2.8 million to 4 million, an increase of 43 %. [110] Over that same period, the value of spreader and cutter imports has jumped 266 %. [111] This suggests that increased investment in machinery and technological innovation may already be contributing to a reduction in job growth in garments and textiles in some countries in Asia. This observation is supported by various other analyses of job growth in major GTF countries. For example, a 2017 World Bank jobs diagnostic in Bangladesh found that jobs growth in the key garment and textile sector remained 'stalled' despite decent GDP growth. [112]



Source
Own calculations using data from the UN Comtrade database (https://comtrade.un.org/data/)

Chapter 5. Drivers of Technological Adoption

The changing economics of technological adoption

In the last decade, the cost of many technologies used in textile and garment production has decreased significantly. In many cases, prices down 50–75 % in this time period. For example, a basic semi-automatic sewing machine with automatic trimming capabilities costs approximately $ 300 now, compared with $ 1,000 two decades ago. One factory that recently invested in an automated hanger system noted that the cost of the system had dropped by nearly 75 % since they first started considering the product. Another factory which invested in an automatic fabric spreader noted that it cost one third of what it would have ten years ago. Despite cost reductions, automated lines at garment factories remain more expensive than manual lines, with one industry source indicating that they could cost three times as much.

As costs fall, payoff periods have decreased significantly. For some technologies, payoff periods are very short. For example, a factory in Cambodia reported that the payback period for their investment in both automated hanger systems and automated cutting machines would both be less than two years. For many of the current technologies being adopted by garment factories in Southeast Asia, short payoff periods of 2-3 years are common. This is part of a broader trend in investments in automation. Deloitte found that the payback period for an investment in a welding robot in the Chinese automotive industry, for instance, was 5.3 years in 2010 but on track to fall to just 1.3 years in 2017.[113]

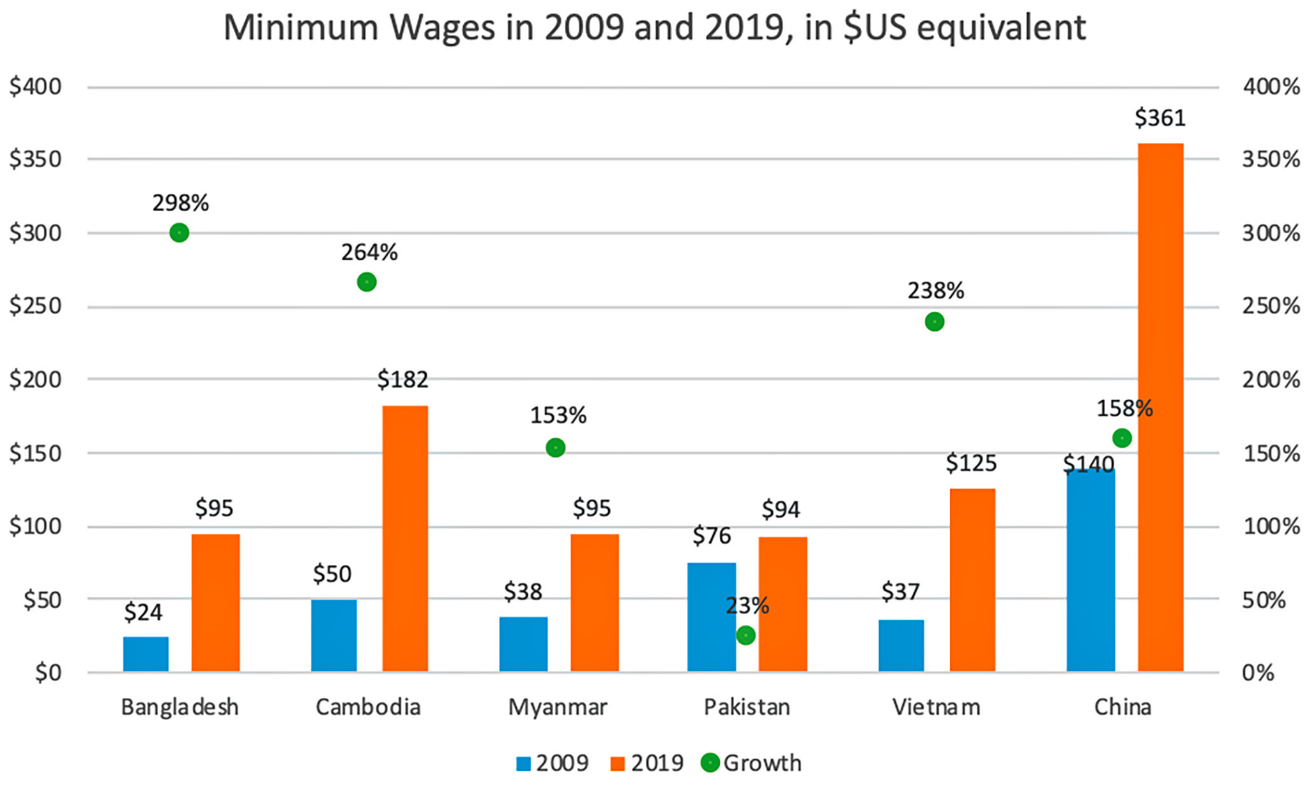
New technologies can significantly enhance productivity and capacity. While productivity growth will be specific to the factory, examples reported by factories include the following:

- New automatic embroidery machines – 48 % increase in efficiency
- Auto-marker for cutting – 20 % increase in efficiency
- Automatic screen printing machines – increased capacity by 50 %.
- Automatic fabric spreaders – 100 % increase in efficiency

Beyond the productivity and capacity gains, automation can also help reduce costs through reducing waste and resource use. For example, one factory that introduced automatic spreaders noted that they reduced waste. Another factory noted that their investment in auto-markers for cutting reduced material utilization by 5 %.

At the same time that automation costs have fallen, labor costs in many of the world's leading garment and textile producers have grown significantly. Minimum wages in key garment producing countries have grown significantly, even in US dollar terms, which is important because many purchasing agreements are denominated in US dollars or Euro, not local currency. In Bangladesh, minimum wages have increased nearly 300 % while in Cambodia they have increased 264 %. In Pakistan, the minimum wage has increased from 6,000 rupees in 2009 to 15,000 rupees in 2019, however the currency has also depreciated significantly over this time, resulting in lower gains in US dollar terms.

Investments in automation reduce the amount of labor required by factories, thereby reducing their total labor costs and the negative effects of wage growth. Much like return on investment, reduction in labor requirements will vary between factories, as they are shaped by a range of factory-specific items. However, a few anecdotes evidence the fact that some technologies can significantly reduce labor requirements. One Cambodian factory reported that the introduction of automatic cutting machines would reduce the number of laborers by 75 %. A Myanmar factory noted that the same machines would reduce labor costs by 80 %.



Source
Own calculations using data from the UN Comtrade database (https://comtrade.un.org/data/)

Improving quality, speed and data collection

Beyond the simple ROI calculations, automation is enabling factories to improve quality and speed to market while maintaining careful oversight of production through enhanced data collection. Automation helps factories improve quality, as each cut and sew can be precisely programmed, whereas manual production led to greater variation and dependence on manual skill. Automation also helps improve speed, completing the same amount of cutting and sewing in less time, without sacrificing accuracy. Factories have noted that these considerations help them to further reduce costs and improve factory-wide efficiency. They can help factories stay more abreast of production, which can contribute to winning additional orders.

Automation provides transparency and allows management to closely monitor production in ways that were not previously possible. Automatic hanger systems and RFID tags allow management to monitor line flow in real time, and identify and address bottlenecks to increase production efficiency. They can also facilitate more accurate data sharing with buyer. Automation also helps factories detect defects and problems earlier. One factory noted, "Sometimes workers try to hide mistakes but machines do not do that. The auto cutter inspects to make sure it is cut correctly."

Constraints on technological adoption

Though prices on automated technologies have come down, they can still be significant for many garment factories. Prices of automatic machines vary significantly based on the quality and numerous other factors, however a limited number of publicly-available prices evidences the significant capital costs of automation:

- Automatic fabric spreader – $ 35,000 [114]
- Automatic cutting machine – $ 80,000 to $ 120,000
- Automatic bar tack machine – $ 3,000 to $ 5,2000 [115]
- Automatic pattern sewing machine – $ 8,000 to $ 13,500 [116]
- Automatic pocket setting machine – $ 30,000 [117]

Even for a small or medium sized garment factory, the costs of automating the entire facility at once could be millions of dollars. This is beyond the reach of most factories, given that many operate with single digit profit margins. Instead, many small and medium sized factories take an incremental approach, purchasing a small number of new machines every year, as funds permit.

In developing countries where garment and textile production is concentrated, businesses often face major business environment challenges such as poor electricity or insufficient access to capital. As factories automate, steady and affordable electricity will be increasingly important for businesses to stay competitive. However, many of Asia's current garment and textile hubs have weak to moderate electricity quality, with regular power outages and voltage fluctuations that present major challenges for automation. Often, factories use backup generators, though these can cost four to five times as much per hour to run while also being significantly worse for the environment. At the same time, obtaining capital to invest is often a challenge, because of weak banking systems. This is especially difficult for smaller factories, or factories that are located only in countries with weak banking systems. These factors can constrain technological adoption in many garment and textile producing countries in Asia, and help improve the economics of reshoring.

Factories adopting new technologies often face challenges learning new systems and integrating them into existing manufacturing processes. Even for management, there is a learning curve with new systems. Systems often come with a range of functions. For example, beyond the ability to automate sewing, some new advanced sewing machines can also provide notifications when maintenance is needed. However, not all factories take advantage of this feature. Likewise, automated hanger systems produce very useful data on production, however not all factories are fully integrating this into planning. These barriers can sometimes dissuade investment if management does not believe it has time or financial resources to properly utilize new technology.

Uncertainty around future orders also dissuades investment. The vast majority of factories operate on short-term orders, without guarantees of future contracts, even though they may have long-established relationships with buyers. For factories with more unpredictable orders, this uncertainty can decrease investment, especially for specialty technologies that may only be helpful for a small percentage of orders. For example, an automatic pattern sewing machine may be very useful for a subset of orders, however with guarantees about future orders that would also use the machine, the factory may choose not to invest. These drawbacks can be offset if there are businesses that rent specific machines, but these may only be available in larger supplier countries. While not always the case, uncertainty can be greater for smaller factories or those not that are not part of a larger supplier group.

Chapter 6. Implications of Technological Adoption

Where will garments and textiles be made in the future?

Technology in the GTF sector will change supply chains, and redistribute global production. There is growing consensus that technology will reorder supply chains. McKinsey argued in a 2017 report that "the traditional supply chain setup is now being challenged and as labor costs converge, mass-market brands and retailers are starting to more broadly rethink their sourcing and production models." [118]

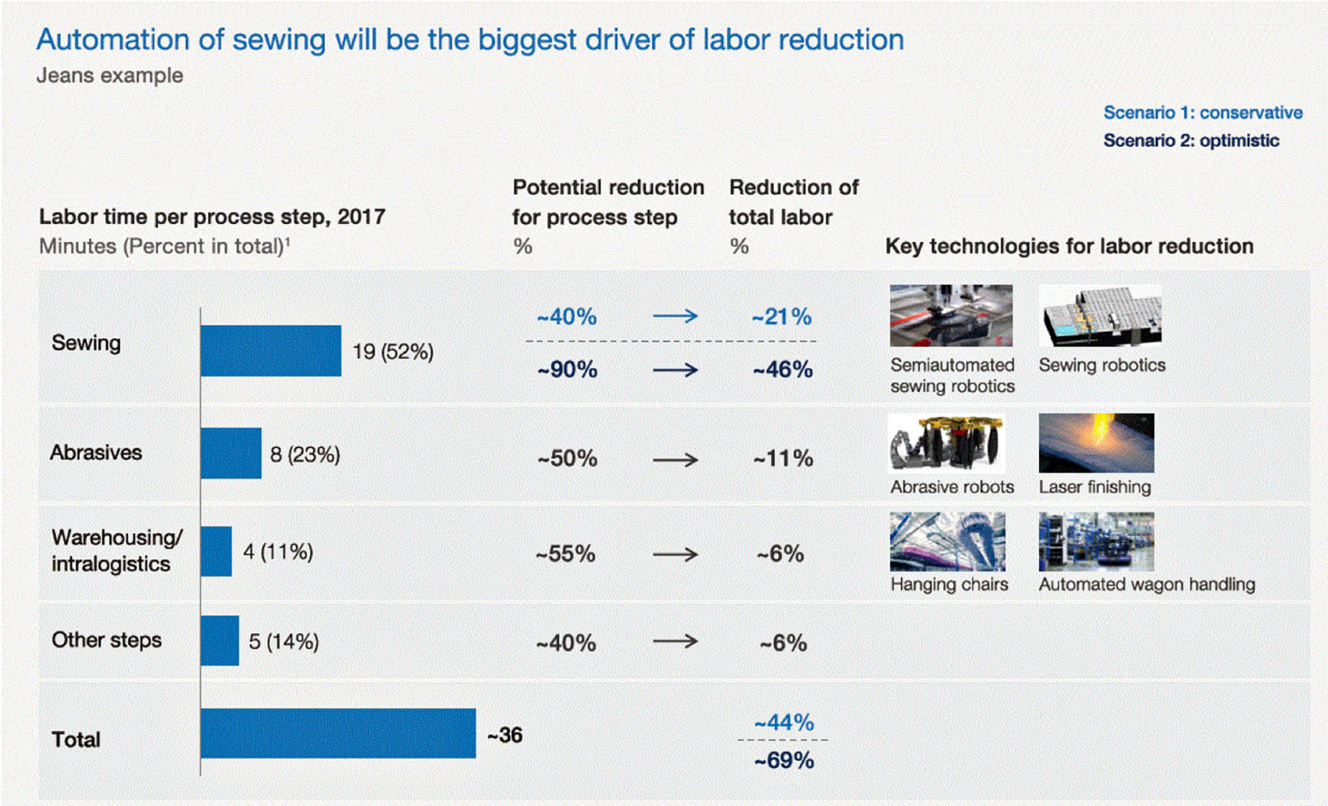
There is consensus that supply chains will change, but not a consensus on how and when. In a 2019 ILO paper entitled, "The Future of Work in Textiles, Clothing, Leather, and Footwear" the authors argued that the consequences of technological change will be most severe for least developed countries. For least developed countries, they predict a "rocky road ahead," arguing that these countries "do not currently have the same resources or capacity to invest in, or attract foreign direct investment into, new technologies or innovation". For middle income countries, they face a "challenge of restructuring" in order to maintain or upgrade their role and position in global supply chains. For developed countries, the ILO predictions are largely positive. They envision continued growth of creative design tasks in high income countries, as well as investment in robotics and automation. They predict that this is likely to "lead to continued net re-shoring of the manufacturing of these niche and high end products in the future." [119]

Other studies have also found that many jobs in developing countries in Asia are at high risk of automation. A 2016 ILO study found that the GTF sector was among the "most vulnerable" to extensive displacement of workers by technology. They argue that the share of workers at risk of automation in the sector was as high as 64 % in Indonesia, 86 % in Vietnam and 88 % in Cambodia. However, a 2017 McKinsey study which looked at the automation based on amount of work hours instead of jobs, found that only 16 % of current work activity hours in China could be automated by 2030. [120] Even in a scenario of rapid transition, they found that 31 % of work activity hours would be automated by 2030. [121] While exact estimates vary, there is consensus in the literature that automation is currently, and will continue to reduce the labor required to produce a garment.

Some industry sources have pushed back against these dire predictions of job losses, noting that such dramatic changes are not economic or part of their sourcing plans. For example, the CEO of Crystal Group, the world's largest clothing maker, said in a 2018 interview that high tech sewing robots won't replace many of their workers in the near term because "they still can't beat cheap human labor on cost." [122] There are also significant costs associated with automation, which suggests that its adoption will be gradual.

The future GTF sector will include highly automated destination country factories, nearshored factories as well as less automated factories in Asia's current garment hubs. This is the 'multi-speed' sourcing model that a number of industry experts have cited as their expectation for the future of the industry. While these facilities will compete with one another to an extent, they will also largely both complement one another, specializing in production of different types of goods of different qualities, often for different markets.

Other trends in the sector seem likely to mitigate the job-reducing effects of technology, especially the projected growth in the overall size of the sector. As a baseline scenario without major changes, one estimate projected that total clothing sales would "reach 160 million tons by 2050 – more than three times today's amount." [123] Notably, growth is projected to be concentrated in developing markets in Asia, particularly China and India. In these two countries, growth rates are among the highest in the world, in the double digits. [124] Asian markets are not just growing quickly – they are already large. According to McKinsey, "greater China" is "expected to overtake the US as the largest fashion market in the world in 2019." [125] Because the overall size of the garment sector is growing every year, new technologies do not have to result in a zero-sum game. A nearshored facility in Turkey could take production from a factory in Bangladesh, which could then reorient production to serve growing Asian markets. These changes are also noted by the ILO which observes that "many LDCs (least developed countries) are currently highly dependent on exports to markets in North America and Europe, but this may change over time as domestic demand for TLCF (textiles, leather, clothing and footwear) continues to increase in Asian countries such as China and India, and eventually in Africa." [126]



Source

McKinsey & Company, "Is Apparel Manufacturing Coming Home," 2019.

Other factors that could mitigate the job-reducing effects of technology include the location of key input suppliers and proximity to raw materials. One of the key factors that shape total costs for GTF production is cost of inputs. Production costs can be significantly lower if key inputs are proximate. Many of the key suppliers of fabric, yarns and other inputs are already located in Asia, giving these countries a notable competitive advantage. China and India are also key sources of important raw materials, as they are the top two producers of cotton globally. Given these counterbalancing factors, many industry experts believe that Asia will continue to play a leading role in the GTF sector in the future.

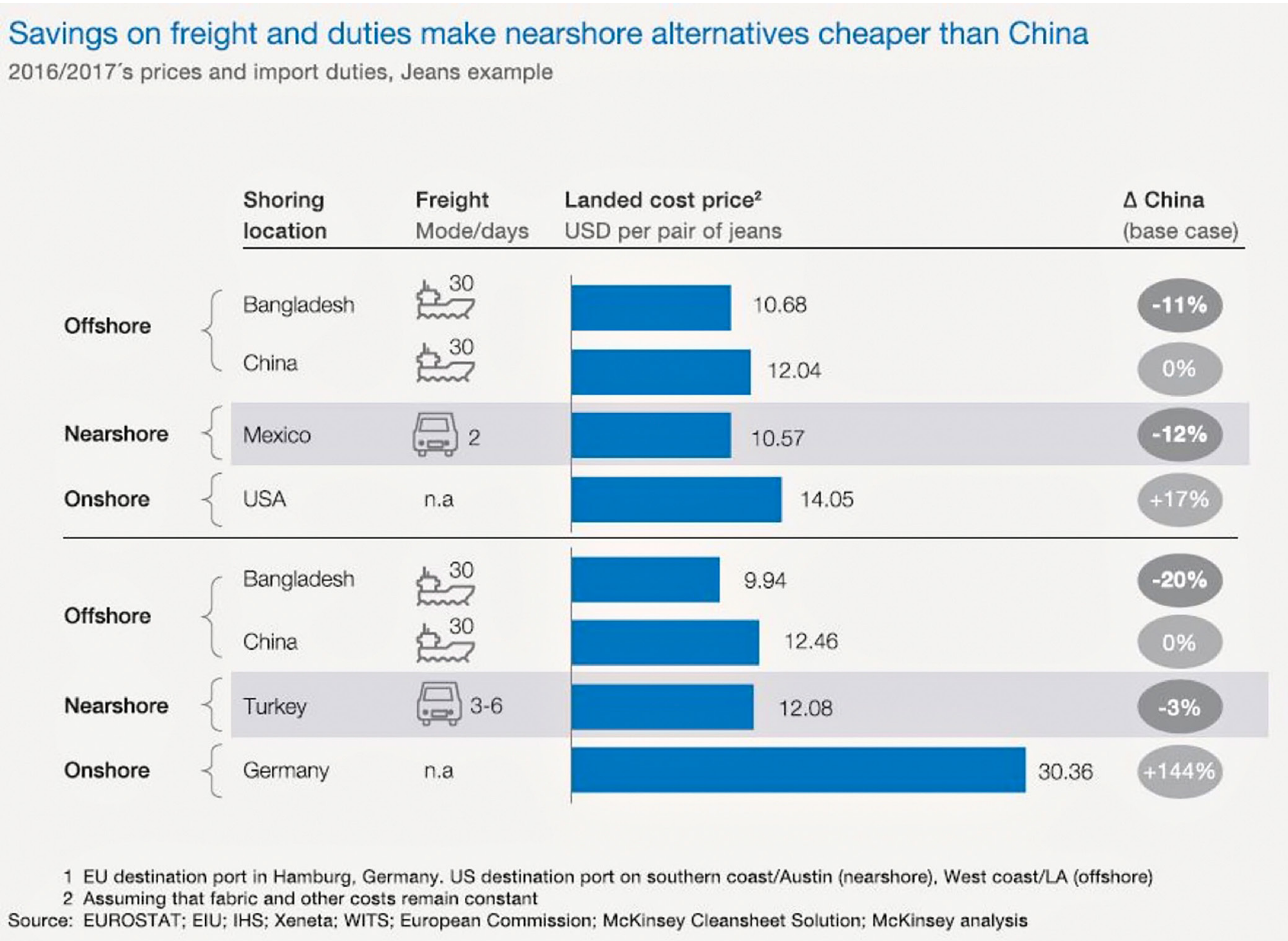
Lastly, as China's economy increasingly moves away from GTF production towards other industries, this could mitigate job losses due to automation elsewhere in Asia. One of the most regularly cited locations for reduction in GTF production is China. Amongst global sourcing executives surveyed in 2017, "62 percent said they expected China's share of their companies' sourcing to decrease between now and 2025," though this figure decreased somewhat since 2015, when "74 percent of CPOs (chief purchasing officers) expected China's role to decline." [127] These declines in China are directly connected to growth of GTF production in other countries, including Vietnam and Myanmar, as Chinese factories seek out new hubs of production.

Though Asia will continue to play a major role in GTF production, a number of industry sources argue that countries near final destination markets will benefit, as brands nearshore production. As automation reduces the share of production costs owing to labor, other factors such as time to market and logistics costs will take on a greater importance in location decisions. McKinsey found because of automation, lower transport costs to nearby countries and increasing labor costs in Asia, "costs are equalizing, even in shifts from low-cost countries, such as Bangladesh, to nearshore markets. If a US company were to source a pair of jeans from Mexico instead of Bangladesh, the product's margin before SG&A (selling, general and administrative) would increase by about 3 percentage points." [128] Nearshoring could have the effect of de-globalizing GTF trade, as destination countries increasingly source from nearshored markets, giving the GTF trade a more regional composition.

Reshoring will be helped by an increasing focus on speed to market and in-season reactivity, which is contributing to an increased focus on agile and on-demand production.[129] Fashion cycles that were once six months are now no more than six weeks and even faster for some retailers. Start-ups are creating new pressures on existing brands. With automation and data analytics, they have adopted agile-made to order production, forcing larger brands to follow "aiming to respond more rapidly to trends and consumer demand. The result is likely to be a rise in just-in-time production, reduced levels of overstock, and an increase in the importance of small-batch production cycles." [130] Mass market brands will have to adapt to this but do not need to "apply speed models to their full assortment;" instead they must aim to "strike the right balance in a multimodal sourcing strategy in which low-cost countries and traditional production will continue to play a big role." [131]

Case Study: McKinsey Approximation of Nearshoring and Reshoring Costs

As automation increases productivity in the GTF sector, it is changing the relative costs of production. In a 2018 report entitled, "Is Apparel Manufacturing Coming Home?" McKinsey reviewed the relative production costs between leading Asian manufacturing hubs, as well as nearshored and reshored production locations in North America and Europe. They found that, for the US market, nearshoring production to Mexico was already less expensive than production in either China or Bangladesh, even without selling a higher percentage of clothes at full price. For Europe, nearshored production in Turkey was less expensive than China, though still higher than importing from Bangladesh. Notably, reshored production in the US was only 17 % more expensive than China. In Germany, however, the costs were 144 % higher than production in China.



Source
McKinsey, "Is Apparel Manufacturing Coming Home?" 2019, pg. 10.

Still others argue that countries proximity to raw materials will becoming increasingly important, and that these countries will benefit from the restructuring of global supply chains. These factors have already played a role in some reshoring decisions. For example, the Tianyuan garment factory in the US was "drawn to the southern US – a region in which the garment industry was especially impacted by outsourcing – due to the low cost of power and close proximity to both its target consumers and cotton producers." [132] However, this also bodes well for the future of the GTF sector in Asia, as both synthetic and natural raw material production is concentrated in Asia. [133] India and China are both major cotton producers, and Pakistan has significant domestic cotton production which feeds its GTF sector. Bangladesh can source raw materials from neighboring India, though Myanmar and Cambodia are more dependent on material imports from distant markets.

Because wages and raw material costs have a significant impact on total production costs, they will make reshoring less attractive in countries with high minimum wages and no raw material production. The difference in reshoring costs between developed nations is clearly demonstrated in the McKinsey study. Germany is not a cotton-producing country and therefore would very likely face increased raw materials costs for denim when compared with other countries that have cotton production such as the US. This was part of the reason that McKinsey found that the cost of reshored production of a pair of jeans in Germany would be more than double that of the US. [134] This demonstrates a key point: not all potential locations for reshored production are equally competitive.

Nearshoring and reshoring can have not only a strong economic case, but also contribute to sustainability goals and facilitate the adoption of circular value chains. Reshored facilities can be connected directly with the retailer's in-country network, using that to collect and recycle used garments.

Social and labor implications of technology

Occupational safety and health

One area where automation has the most clear-cut benefit for workers and businesses is in the improvement of occupational safety and health. Removing workers from manually performing numerous tasks at a factory has direct health and safety benefits. There are numerous areas where automation directly improves worker health and safety including:

- Automatic fabric cutters eliminate the need for workers to manually operate blades, reducing the risk of injury from close proximity to the cutting device.
- Automatic hanger systems reduce repetitive movements, meaning that fewer workers would be at risk of injury due to these movements.
- Automation of dying can reduce or completely remove worker contact with dangerous chemical substances, reducing the risk of disease.
- Automation of shoe production reduces worker exposure to hazards glues and binding materials.

Wages and working conditions

Because of the close relationship between wages and productivity, automation of GTF production holds promise to boost wages due to its productivity-enhancing effects. Of course, some of the financial benefit of automation will flow to businesses, to both repay capital costs and as a rate of return on invested capital. However, some of the benefits of automation will also be enjoyed by workers, a reflection of their higher productivity and the skills that often accompany that. Workers with more skills, including the ability to program, repair, and work with automated machines, will benefit the most, though moderately skilled machine operators may also enjoy higher wages. Workers are very likely to see higher wages in areas where automation complements, instead of competes, with labor. For example, workers on a line that is upgraded to an automated hanger system are very likely to receive higher pay. This has already happened at some factories in Southeast Asia, though results are factory specific. However, there is also the potential for some workers to lose, notably those whose jobs are replaced by automated machines, creating the potential for bifurcation of the workforce into a higher skilled group of workers that benefit from automation and a lower skilled group that lose out.

Businesses may seek more flexibility in working hours, to help increase utilization rates on machines and boost overall factory productivity. When businesses make investments in expensive automated equipment, they need to use the machines as much as possible to maximize their return on investment. This could include using automated machines on multiple shifts, weekends and at other times that traditional manual work was not done. This may result in an increase in non-standard working hours. It may also increase the use of overtime, or potentially excessive working time. However, automation may also produce the opposite result in some factories. Switching from manual to automatic cutting may reduce the overall time needed to cut fabric due to increased efficiency, thereby reducing the need for overtime and multiple shifts.

Industrial relations

Automation will reduce the bargaining power of many workers in developing countries. As automation becomes increasingly affordable, employers will have new options to consider when deciding how to organize production. Increasingly, they will opt to automate steps of production because it is more cost-effective than producing with manual labor, while also improving quality and providing other benefits. Employers will face increasing competitive pressures that will limit their ability to pay higher wages, especially those that continue to rely largely on manual labor.

Automation increases the need for improved social dialogue and opens new opportunities for data-based dialogue and bargaining. Production data from automated technologies can provide new data on productivity which can better inform stakeholders in the factory and serve as an evidence base for dialogue and bargaining. New technologies also create a need for robust dialogue between management and workers, around areas such as skills needs and training on new technologies.

Automation presents additional risks for industrial actions. Change in production processes can be a challenge for both workers and manufacturers. While employers may feel pressure to introduce new technologies in order to remain competitive, they may be reluctant to share this information with workers for fear of provoking some type of industrial action. This limits prospects for collaborate engagement, and highlights the need for improved education of workers and employers to help facilitate better dialogue and trust-building around introduction of new technologies.

Skills

Automation will have significant implications for the skills demanded by private sector, reducing demand from some skills. Automation will likely reduce demand for skills that can be done by automated machines, such as manual spreading and cutting, manual sewing, manual ironing and others. While there will still be demand for sewing skills in the GTF sector, demand will increasingly shift to higher levels of skill to sew more advanced garments that cannot be replicated by automation.

Automation will increase demand for skills in other areas. Among the skills most regularly cited as in demand are skilled staff to repair and program advanced machines. The ILO noted that new skills will also be in demand in areas such as "design, finance, product development, logistics, marketing, sales and customer service. Workers trained in ICT and science, technology, engineering, and mathematics (STEM) disciplines will be in particularly high demand across all industries in all countries." [135] This echoes the findings of the World Economic Forum, which expects "strong employment growth across the Architecture and Engineering and Computer and Mathematical job families," while noting that there will also be "a moderate decline in Manufacturing and Production and a significant decline in Office and Administrative roles." [136]

Automation presents a special risk for women, if cultural stereotypes about women and technology reduce women's access to new jobs. In some major GTF producing countries, parts of the sector exhibit stereotypes against women, including beliefs that it is not appropriate for them to operate or maintain more advanced machinery. Similarly, in some locations there are lower levels of women's enrollment in technical and vocational education and training (TVET) and IT programs. This prevents women from receiving the training and developing the skills necessary to excel in the job market of the future.

Introduction of automation may bifurcate the workforce into two groups: a low-skilled group of operators and a high-skilled group with IT, repair, programming, and soft skills. Potential polarization of the work force into low-skilled and high-skilled groups has already been found in developed countries that have experienced significant automation. At present, there is limited research on this in developing countries. One study found that developing countries are not seeing the same level of polarization as developed countries. However, they found some cases such as Indonesia where select semi-skilled jobs (operators) were decreasing. Other countries, showed slow growth of semi-skilled jobs (operators and technicians) but not reductions as seen in the United States. [137]

Workforce bifurcation is especially a risk in sewing. At present sewing departments are staffed with hundreds or thousands of workers, the vast majority of whom have skills and some who have built a very strong skill set through years of experience. In most sewing departments there are few workers who would be considered 'unskilled'. However, as various steps in the sewing room are automated, it is possible that a large group of semi-

Future Jobs in Bangladesh

In 2018, the World Bank published a report on skills needs in Bangladesh for the jobs of tomorrow. The report addresses many of the same skills-related questions that this report faces, and its themes reflect the needs identified in this analysis. The report outlines three key pillars of action to tackle the skills challenges that Bangladesh faces. They are:

- "Improving institutional capacity for better linkage between supply and demand sides of skills towards more adaptive skills development system.
- Re-orienting skills supply to prepare youths for unpredictable skills demand and uncertain economic environment.
- Greater involvement of the demand-side of skills – private sector participation in skills development."

The report makes explicit mention of many areas that were also brought up by various industry sources during this research. They include the need for additional training in soft skills, cognitive and problem solving skills, and information technology skills. The report also highlight the need for additional practical, hands on skills development especially in science, technology, engineering and mathematics (STEM) and expanded training opportunities for mid-career managers.

Source: World Bank, "Skills for Tomorrow's Jobs: Bangladesh," 2018.

skilled seamstresses are replaced by low-skilled operators of semi-automatic and automatic machines and a smaller cadre of high-skilled programmers, technicians and repair persons.

As advanced technologies become more common, the need for training partnerships between public and private sector will grow. In many countries in Asia, the private sector often notes that public TVET programs do not produce the necessary skills, and therefore private businesses are forced to provide on-the-job training for new recruits. As automation advances, skills will become even more specialized and it will be even harder for public TVET programs to provide the skills needed. Similarly, reliance on individual employers to conduct training will produce suboptimal outcomes. Higher turnover rates (44 % in Cambodia) disincentive this retraining.[138] This is because the benefits of training primarily reside with the worker, who can move to another business and relocate those skills. If businesses pay for the training, they have little recourse with staff who leave soon after training is complete, a significant disincentive to training.

However, the semi-automatic and computer controlled machinery that is being adopted now will change job availability and skills needs. Many garment factories are adopting technology over time, introducing a few new machines each year. Often businesses retrain existing workers on these new machines. However, some businesses have also noted that they are reducing the overall size of their workforce, often through attrition. Workers that leave are not simply not replaced, while workers that remain are moved around to other roles in the factory if their position is automated.

Environmental implications of technology

The environmental cost of GTF production is significant. According to the Ellen McArthur Foundation, the "total greenhouse gas emissions from textiles production, at 1.2 billion tonnes annually" which they state is more than all international flights and maritime shipping combined. Textile production uses approximately 93 billion cubic meters of water per year, much of it from cotton production. 20 % of industrial water pollution globally is attributable to the dyeing and treatment of textiles.[139] The vast majority of materials used in GTF production, some 97 %, are virgin, with only 1 % from closed loop recycling of garments, textiles and footwear.[140] Over the next 30 years, natural resources required to feed demand for garments is projected to triple, due mainly to the growth of the middle class in Asia.[141] Reduced garment costs have contributed to 60 % growth in number of garments purchased between 2000 and 2014, as well as a 50 % reduction in the length of time a garment is kept.[142]

The environmental costs of GTF production are not evenly distributed or borne by consumers, but instead fall disproportionately on those who live near factories. Communities located in and around GTF factories benefit from the employment that they generate, however they also experience negative externalities of production, especially pollution. This is especially acute in regards to water pollution, which results from dyeing and leather tanning. Negative effects of discharging untreated wastewater including polluting local rivers that are used for fishing, drinking or bathing. In India and Bangladesh, significant amounts of untreated, chromium-tainted wastewater have been released, significantly affecting nearby farmland.

Technology can help improve environmental sustainability in existing value chains, through both general efficiency gains as well as targeted applications to improve environmental outcomes. Many of the technologies being introduced in the garment sector help to improve efficiency and productivity. For example, waterless washing can reduce water consumption which benefits the factory by reducing their overall costs for water use. Likewise, energy efficient dryers can reduce energy use, providing an economic and environmental benefit. All other things being equal, increased production at a facility also reduces the environmental footprint of each garment that is attributable to that facility. For example, if a factory that produces 600 shirts an hour can increase throughput to 900 shirts an hour, the cost attributable to lighting the facility will not increase. Through these economies of scale, the total environmental costs per garment can be reduced.

Big data and artificial intelligence can help reduce overproduction through improved planning. At present a meaningful share of garments, approximately 3 % of production, are disposed of because they cannot or have not been sold. AI has the potential to improve planning, which can help buyers refine orders and therefore reduce the number of garments that are destroyed without being used.

Increased digitization and automation in the production process can directly reduce wastage. A wide array of technologies can contribute to this. For example, more efficient layouts using CAD can reduce the fabric wasted in the cutting process. Improved accuracy in cutting can also help reduce defect rates, as can automation of steps in the sewing process. These technologies can help to reduce significant waste in the production process, which is estimated at 12 % of materials used.[143]

New technologies and processes can reduce the use of natural resources in garments, providing environmental benefits and cost savings. Energy efficient technologies, such as dryers, reduce demand for electricity which is often generated from non-renewable resources in Asia's garment production hubs. New jeans finishing processes, such as Levi Strauss' Water<Less program, can help reduce demand for water. According to Levis, this process reduces water usage in one pair of jeans by up to 96 %, and has saved 172 million liters of water since introduction.[144] A range of other water saving technologies, such as waterless dyes, water efficient washing machines and in-factory water recycling. Improvements elsewhere in the value chain, such as sustainably farmed cotton or increased cotton recycling, can also help reduce overall sector water demands.

Technology can also help to monitor and reduce pollution. There are numerous technologies that contribute to reducing pollution, in numerous different parts of GTF production. For example, Stahl has developed a leather tanning process that reduces water consumption and eliminates chrome for the tanning process.[145] The process depends on using molecules specifically designed to bond to all parts of the collagen, the protein in leather, which helps produce products of similar quality to chromium-tanned leather but without the environmental dangers traditionally associated with tanning.

The connected technologies of I4.0 provide new ways to monitor environmental performance and compliance. Buyers and regulators have traditionally depended on inspections and audits to ensure that GTF factories are abiding by national laws, codes of conduct, and other standards. However, new interconnected technologies create vast amounts of data that can be accessed and monitored in real time. For example, China's "Institute for Public & Environmental Affairs" has created a Blue Map, an interactive online resource that shows water and air pollution from factories in China in real time. [146] The map allows users to see the pollution from factories as well as the brands that source from those factories. This type of real time monitoring provides valuable data, a model which could be expanded and incorporated into buyer operations in other countries as well as various standards. These types of new technologies allow buyers and regulators to move away from antiquated inspections and audits and towards new monitoring regimes based on sensors and smart technologies. For example, Zero Discharge of Hazardous Chemicals (ZDHC) Roadmap to Zero program requires testing and reporting at least two times per year. New technologies may allow for continuous monitoring, an opportunity that ZDHC could explore integrating into future revisions in the standard.

Technology can also facilitate structural change that improves environmental sustainability in GTF value chains, but destinations markets play a key role. One of the most notable changes is the location of factories, specifically the role of technology in making nearshored or reshored factories competitive. Factories located closer to destination markets require less transportation, thereby reducing the environmental implications associated with logistics. Technology can help improve efficiency in retailing, as it already has by helping to move in-person shopping online, which is less resource intensive. Notably, technology such as body-scanning should be able to help reduce return rates for e-commerce, which are around 40 % of online purchases. [147]

Among the most important areas for destination markets is to improve recycling. Every year more than "USD 500 billion of value is lost every year due to clothing underutilization and the lack of recycling." [148] Some countries perform better than others. Germany, for example, collects 75 % of textiles, with only 25 % going to landfills, though this ratio is increasing due to poor quality garments that do not allow significant reuse or recycling. Technologies are being developed that can aid in textile recycling, such as automatic sorters mentioned above. Governments in the EU could hasten technological development and roll out by increasing the incentives to recycle, for example by introducing requirements for companies to take back used garments, improving sectoral recycling initiatives, or by increasing costs of disposal. Improving recycling in destination markets would have significant knock-on effects, contributing to environmental improvements elsewhere. Notably, recycling cotton could contribute to a significant reduction in demand for new cotton. Because garment demand looks likely to continue to grow in the coming decades, improved recycling is especially important in helping to improve sustainability in the sector. Investments in recycling are already allowing garment and textile recycling to expand. Eforts to extend the life of garments are also gaining pace, including reuse, which according to one project is "expected to growth 1.5 times the size of fast fashion by 2018." [149]

Lastly, technology should help to better internalize the externalities of garment production and waste. Consumer preferences for fast fashion have massive externalities that are not captured in the price of garments. These include costs of pollution, waste, and working conditions of workers in many steps of production. As the Ellen McArthur Foundation notes, there is a need to focus on "tackling the root cause of the system's wasteful nature directly, in particular, low clothing utilisation and low rates of recycling after use." [150] Technology can help do this, providing transparency and information about garments to buyers. There is a special need to draw attention to activities that are especially bad for the environment, such as air freight of garments and certain types of water pollution.

Without improved transparency, data collection, and regulation, technology risks encouraging unsustainable consumption. While much of the recent literature talks about the benefits of technology for sustainability, it is also clear that it can facilitate unsustainable consumption. Technology can help reduce production and distribution costs for garments, lowering prices and driving additional consumption. However without many of the externalities social and environmental externalities properly priced in, technology could help exacerbate systemic problems in garment production. It is important to re-emphasize that there remain inherent conflict of interest between businesses and sustainability. Most notable among these is underutilization of garments, which is the greatest single driver of waste in the sector.

Chapter 7. Recommendations for German Development Cooperation

Global

Begin dialogue on introducing factory data into various standards regimes. As factories collect ever greater information on production, the data generated presents new opportunities to learn about and reform harmful buying practices. As more data becomes available, various standards should begin to require disclosure of supplier data, even if anonymized. At a minimum, this should be used to conduct further research to identify relationships between order characteristics and negative environmental or labor outcomes. Another possible application is to capture emissions data from GTF production. These types of data could then be used to develop standards or guidelines about buying that would encourage improved practices. They could also be shared with factories so they can reflect on their own processes and look for areas to improve performance. A further step would be for standards-setting organizations to require disclosure of certain data as a requirement for certification. These types of disclosures should be developed in consultation with private sector, respecting the need to sometimes keep data private for competitive reasons, and always ensuring proper data security measures are in place.

While growth of data is vital to helping consumers make informed choices, the proliferation of data, standards regimes, and transparency initiatives can also be difficult to digest. The proliferation of standards and information risks confusing average consumers who may be unable to differentiate between different standards. It may also be a challenge for producers who face multiple standards from different buyers. Improved clarity and harmonization of standards both within the sector and also with multi-sectoral standards may help improve their traction with consumers and ease the compliance burden on manufacturers.

Review the benefits and risks of linking duty free market access to gradually improving environmental performance. Current EU trade preference schemes including the generalized system of preferences (GSP) and Everything but Arms (EBA) provide preferential access to the EU market for businesses in a wide range of countries. The GTF sector is the primary beneficiary of this scheme. Germany, in conjunction with other EU members, could examine the pros and cons of adding additional environmental and labor requirements to these trade preferences. These programs could be reoriented to give preference to garments and textiles that are more sustainably produced. For example, preference could be given to garments that are easily recycled. Any steps to enhance the environmental and labor standards of trade preferences should be carefully considered, widely consulted, and avoid discriminating against small and domestic enterprises.

Host country

Business environment reforms can help prepare countries to take advantage of technology to make their GTF sector stronger. Given the increased importance of electricity and connectivity for automated businesses, GIZ could consider initiatives that support broader infrastructure improvements. It may also be useful to begin providing information to host country governments about I4.0 technologies and help them consider their adoption and integration. For example, engagement with customs authorities could help them to consider digital interfaces that are compatible with blockchain-based smart contracts. Other potential business-environment related initiatives could include:

- Working with host country governments to reduce incentives for businesses to overwork employees. For example, Myanmar currently allows second shifts only with government permission, which has been withheld from some factories. This forces factories to have existing workers engaged for longer hours.
- Review tax systems to ensure that it fairly taxes both labor and capital.

At the same time, most major garment producing countries could benefit from diversifying their manufacturing base and engaging in higher value added sectors. GIZ can play a role here through assistance on development and implementation of economic development strategies and trade strategies. However, these strategies, as well as the skills training, finance, and sustainability steps outlined below, must all take into consideration the specific situation in these different countries. These types of exercises should be cognizant of the shifts occurring in the GTF sector and when appropriate, seek to encourage diversification through changes in industrial, trade and education policy. They could also use thorough analysis to determine employment potential in other sectors, and use this, combined with existing strategies, to suggest paths forward for each country.

Skills and Capacity Development

More than any other area, there is a significant need for skills retraining to help workers learn new skills necessary to program, operate, and maintain new machines. As automation is introduced, the demand for many manual skills will decline while other skills, such as IT, repair, and programming, will increase. Given this change it is likely that in the future there could be a significant mismatch in the supply and demand of skills. As such it is vital that countries realign their training infrastructure to focus on these new skill sets. This could require the establishment of new programs, such as an integrated tertiary-level garment engineering program with a heavy IT focus. Some skills retraining could also be facilitated through existing GIZ programs and partnership such as the university linkages or the women's cafes.

Private sector should be involved in identification of skills needs and implementation of training, potentially through public private partnerships. The best way to ensure that skills match the demands of business is to involve private sector, regularly and in a significant way. Regular consultation by government will likely not be sufficient in many countries. Instead, there should be a regular mechanism through which private sector shares insights on skills needs coupled with direct decision making power on training. Private sector should also bear part of the financial burden, either individually or through a contribution to a collective pot. Workers should also bear some burden for training because they benefit directly from this, though it should be means tested. Governments should also support skills development. GIZ could assist in developing or reforming structures that currently inform national-level skills training programs, as well as working on policy issues regarding funding of skills training.

Explore various schemes to incentivize training and improve training outcomes. These should include incentives to encourage factories to increase the level of in-factory training. Programs to do this could include but are not limited the following:

- Singapore-style subsidized individual training accounts.
- Workplace training through public private partnerships. This would include public support, such as a financial incentive, as well as partnership with sectoral bodies such as leading employers' associations. This system could incentivize employers to provide training, mobilizing a powerful potential source of skills and knowledge if the correct incentives are in place. [151]
- Multi-stakeholder training, including government, business, education systems and training institutions, which pool resources. This may result in a range of different training types, including TVET or a dual system. Experiences from other countries "show that training in the workplace is most effective in keeping up with the numerous technological changes in industry. Again, this requires strong involvement from business and well-functioning public private partnerships." [152]

Special efforts should be made to help target groups, including women and persons with disabilities, benefit from automation. New technologies may open up a wide range of jobs that previously had not have existed or been open to workers with disabilities. They may also change the physical requirements of jobs, allowing workers with disabilities to effectively work in parts of the factory that may not have been previously possible. Programs could target inclusion of persons with disabilities to help them build skills, while also helping businesses integrate them into the workforce. Likewise, there is a risk that cultural barriers about women's employment with technology may prevent women from benefitting from technology in the GTF sector. It is vital that women are not left behind by job losses, but are re-integrated into a changing industry and labor market. To do this, skills training will be vital. GIZ could, likely through partnerships, provide targeted training to women to develop skills as well as education to businesses to encourage hiring of women.

GIZ could explore partnerships with German technology manufacturers to help increase training opportunities in major producing countries. The new technologies being introduced in the TGF sector are often expensive, with costs being prohibitive for almost all training schools in these countries. Public-private partnerships between German and other industrial machinery suppliers and national training providers could increase availability of new machines in-country for training purposes. For these companies, this could also provide a significant benefit. It would provide a cadre of trained professionals in country that are able to repair and maintain their machines, increase the prospects that garment factories would select them when choosing automation technologies.

Given the possibility that the total number of employees in the GTF sector may shrink in some places, retraining programs should also help workers move away from garments, textiles and footwear. People need to be retrained in other fields. Over time, the number of jobs in the GTF sector will shrink. The sector cannot sustainably support the number of jobs that currently exist at wages that are fair or mandated by host-country governments. This could be addressed by focusing on soft skills training or other multi-sectoral skills. Language skills are another possible area for focus. These could be beneficial for workers who will operate, repair, and maintain new advanced machinery which is often manufacturing in other countries (and has instructions in a foreign language). These language skills are also useful beyond just the garment sector.

Finance

Increase the availability and/or affordability of credit for investments in sustainable production and technologies. For countries where private sector banks are primarily responsible for extending credit to businesses, this could be done through a targeted subsidy for lending that is directed towards these sustainable investments. For countries where government-run banks extend credit, a policy change could either decrease the relative costs of borrowing for these technologies or set aside a certain share of total private sector lending specifically for investments in renewable technology.

Consider the development of a challenge fund to support research and development. Challenge funds are financing facilities to incentivize and partially underwrite research, development and roll-out of goods and services that are socially beneficial. Challenge funds may be particularly useful to encourage research into recycling and broader circular economy or cradle-to-cradle approaches and technologies that can increase the sustainability of the garment sector.

Environmental Sustainability

Incentivize the adoption of environmentally sustainable technologies through policy tools and appropriate pricing of water and electricity. Governments have a wide range of tools to shape the costs of production, including taxation, tariffs, and pricing for utilities such as water and electricity. These tools should be used to create incentives for garment sector businesses to invest in more environmentally sustainable technologies. Changes could include higher utility prices for water and electricity usage, especially for intensive users. At a minimum, host country governments should review these areas to identify any unintentional incentives which contribute to pollution, waste or unsustainability. For example, a review of tariffs could be conducted to ensure that efficient fabric finishing technologies such as lasers do not face higher tariffs than the machinery used in inefficient methods such as stone washing. These steps could contribute significantly to environmental sustainability.

Support recycling of waste from the production of garments and textiles in major production hubs in Asia. GTF production creates significant waste, with one estimate suggesting that 12% of all materials are lost in the production process. Because production is often geographically concentrated, there is significant scope to support improved recycling of wasted materials from GTF factories. Next steps to support recycling include:

- Study of materials disposal practices in major GTF hubs, identifying areas where recycling of materials would be more beneficial.
- Investigate financial constraints on investment in recycling facilities and consider financial programs that would enable major GTF producing countries to develop robust recycling systems for the sector.

Support increased capacity of environmental regulators. GIZ should support governments to build increased monitoring capacity of environmental harms, including water and air pollution. At present some regulators do not even have basic equipment needed to test water or air pollution. Many also lack skilled staff to perform these functions. GIZ could support environmental regulators to develop testing capacity, laboratories and also examine equipment needs. Support for enforcement could also include regulators in destination countries or third party standards-setting organizations, such as ZDHC. Destination and host country regulators could collaborate to support research about compliance at the brand (as opposed to factory) as well as the country level.

Use data on pollution to improvement monitoring and enforcement of national environmental law and international standards. As garment factories increasingly adopt technology, the data that they capture about factory operations will increase significantly. This is useful to management to optimize production, but can also help to monitor by-products of production such as wastewater discharge and CO2 emissions. This data could eventually be integrated into enforcement by a national government, or could be sent to brands as part of their compliance with various international standards regimes. If clearly and consistently communicated, it could also help consumers understand the environmental implications of garment production and shape consumer habits. This information could be brought together through use of a blockchain, giving end-users confidence in the data's validity.

Explore standards and certifications that help businesses save money while also improving environmental and social outcomes. For example, in conjunction with host governments, standards could be developed for equipment such as automatic cutting machines, demonstrating that they reduce risk of injury at the workplace. If a business met this standard and obtained a certification, that could be linked to reduced insurance bills or employment injury insurance scheme payments. Another potential area to explore is whether remote monitoring from various in-factory sensors could be used by brands, preferably multiple brands, in lieu of duplicate audits.[153]

Build capacity of factories and supplier networks to overcome adoption barriers associated with new technologies, and assist them to maximize the potential benefits of these technologies. New technologies often have barriers to adoption, such as the time cost or lack of expertise needed to integrate the technology into existing operations. At the same time, these new technologies have the potential to significantly reduce the use of natural resources such as water, while also reducing the use of inputs such as fabric or chemicals. These reductions have a significant environmental benefit. Governments could, likely in partnership with knowledgeable third parties, help factories to overcome adoption barriers and train them about how to maximize the efficiencies and benefits they provide, reducing barriers to adoption and maximizing the environmental benefit of these new technologies.

Social Sustainability

Support for education and capacity building of social partners could help promote smoother adoption of automation. For the factories that already have collective agreements, support could be directed to help parties discuss automation plans including workforce retraining. This would benefit workers by helping to mitigate skills gaps, and benefit employers by helping them be ready for new skills needs when technologies are introduced. In all cases where there are unions, it may be useful to educate their leaders about garment sector technologies. This could help them to be more capable to dialogue and negotiate with businesses who are likely looking to automate about automation plans including workforce retraining, which could help smooth the adoption of automation.

Help stakeholders get the right incentives in place so that technological adoption is smooth. Previous academic research has shown that workers must be incentivized to participate in technological adoption because given incentive-based pay structures that are common in the GTF sector, some workers could receive lower incomes during the technological adoption process.[154] Facing temporary pay reductions, some workers may encourage management not to adopt the technology or make the process more difficult. Ensuring that worker and employer incentives are aligned during the adoption process could help technological introduction go more smoothly.

As automation helps factories gather more information on the workplace, dialogue will be needed at factory, sector and national level to develop agreement on data access for other stakeholders, including workers, unions and government. Productivity data is valuable for factory management but also important to other stakeholders, including workers and unions, if for no other reason that some data measures worker performance. As a first step, national stakeholders should begin discussions on data access for workers and unions. This could include discussing access rights to data on operator efficiency, production line data, information on standard allowed minute calculations and performance, or other areas. The government may also have an interest in obtaining data for regulatory purposes, for example to examine compliance with labor law. Another potential area for discussion would be a worker right to obtain factory-collected data on their performance at a regular interval or when they leave their job. Some workers may find this performance data useful when applying for new employment. Another area for dialogue is on requirements for businesses to disclose information collection in the factory. This could mean, for example, that businesses are required to notify workers about all types of information that are collected about them in the factory. There may be scope for GIZ to support dialogue about data access or provide training about data use rights.

Raise awareness about the benefits of new technologies that benefit or complement existing workers. While many GTF businesses in developing countries may be aware of new technologies, they may not be aware of the range of benefits they offer. GIZ could support awareness raising about the costs and benefits of these machines, focusing on ones that raise productivity of existing workers (automated hanger systems) or provide environmental benefits to workers and factories (automated or environmentally friendly dyes). Special focus could be given to technologies that both have an environmental benefit and provide businesses with improvements to the bottom line, for example by lowering electricity or water use. Given the sensitivity around workers being replaced by automation, awareness raising should focus on technologies that are perceived as a 'win-win'. This could be done in conjunction with national labor ministries.

Assistance to factories, such as support for matchmaking services, could help avoid closures and job losses. As automation changes sourcing patterns, some factories will lose orders from existing buyers, jeopardizing their business. However, with support for matchmaking services, factories may be able to find new buyers, especially from growing Asian markets. This could help reduce job losses due to this type of transition. These types of programs could be supported directly or indirectly by GIZ.

Destination country

While many steps can be taken to improve sustainability in major production centers, true sustainability cannot come without policy action in developed countries that import much of the world's clothing and textiles. While these areas may be outside of the mandate of BMZ and GIZ, it is vital that other parts of government recognize that a sustainable GTF sector is a whole of government affair. In destination countries, governments could explore a range of policy areas aimed to increase garment use, internalize externalities, and increase overall sustainability. Potential policy areas that destination country governments could explore include:

- Work to improve garment recycling systems, including programs to discourage premature disposal of unwanted garments.
- Encouraging garment rental businesses, which could help to reduce disposal of garments before their useful life is done.
- Develop systems that require retailers to take back used garments or incorporate the costs associated with the sustainable disposal of the garment into the initial purchase price through a targeted tax.

Consumer education should be prioritized in destination countries, because their behavior plays a major role in shaping brand and factory practices. Consumers often have little knowledge of the social and environmental costs associated with garment production. Increasing their awareness is vital, though this must be accompanied by the provision of additional information so that consumers can make informed purchasing decisions. This education should include not just information about production, but also other parts of the value chain, including the environmental implications of overnight delivery. Increasing consumer education may be more effective if governments use policy tools to internalize some of the negative environmental externalities.[155]

Footnotes

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