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HUMAN CAPITAL DEVELOPMENT AND TECHNOLOGICAL INNOVATION AS DRIVERS OF PRODUCTIVITY GROWTH IN THE TEXTILE INDUSTRY: EVIDENCE FROM UZBEKISTAN

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Abstract *– Uzbekistan's textile industry has grown rapidly since the cotton sector reforms of 2017, yet it remains unclear whether this growth has been driven mainly by the expansion of capacity and employment or by rising productivity. This study assesses the contribution of labour productivity to output growth in the industry between 2017 and 2025 and examines the role of human capital development and technological innovation in this process. The research used secondary data from industry, national and international sources on physical output by product group, employment, exports, education, digital skills and innovation. Output per employee was calculated for five product groups, and output growth was decomposed into employment and productivity components. The results show that employment increased 3.31 times, from about 188,000 to 623,000 people, while garment output rose 7.65 times and knitted fabric output 5.11 times. Productivity growth accounted for 41.1% of the growth in garment output and 26.6% in knitted fabric, whereas output of yarn and processed cotton fibre per employee declined. Export value per employee fell by 39.6% between 2018 and 2025. Higher education coverage increased from 10.6% to 47.7%, and the country rose from 93rd to 77th place in the Global Innovation Index, but research and development spending remained at 0.1% of GDP and basic digital skills remained limited. The findings indicate that growth has been predominantly extensive, with productivity gains concentrated in downstream segments. The article argues that sustaining growth requires shifting from capacity expansion to the joint development of industry-relevant skills, management practices and process innovation.*

Keywords: *human capital, technological innovation, labour productivity, textile industry, skills development, industrial upgrading, digital skills, growth decomposition, value added, Uzbekistan*

INTRODUCTION

Labour productivity is the main source of sustained growth in incomes and competitiveness, and for developing economies the textile and apparel industry has historically served as one of the first steps on the ladder of industrialisation. The industry absorbs large numbers of workers with modest initial skills, yet its long-term competitiveness depends on the ability of enterprises to raise output per worker, improve quality and move from intermediate goods to finished products with higher value added. Whether this transition succeeds is determined to a large extent by two interrelated factors: the skills of the workforce and the technologies that enterprises adopt.

Uzbekistan offers a distinctive case. Following the reforms of the cotton sector, the country moved from exporting raw cotton to processing it domestically: the share of cotton fibre processed within the country increased from 40% in 2017 to 100% in 2025 (UzTextileProm, 2026). Employment in the textile industry rose from about 188,000 people in 2018 to about 600,000 in 2024 (World Bank, 2025). In 2025 the industry employed 623,000 people, produced output worth UZS

134 trillion and utilised US$2.1 billion of foreign investment (President of the Republic of Uzbekistan, 2025). The scale of this expansion is unusual even by the standards of fast-growing economies.

The quality of this growth, however, raises questions. Textile exports reached US$2.6 billion in 2025 (Government Portal of the Republic of Uzbekistan, 2026), which is below the level of US$3.3 billion recorded in 2022 (Movchan & Walter, 2024). In reviewing the results of 2025, the government also pointed to a shortage of qualified specialists in certain areas (President of the Republic of Uzbekistan, 2025). These developments coincide with global changes in the demand for skills: 39% of workers' core skills are expected to change by 2030 (World Economic Forum, 2025), and the textile and apparel sector is only beginning to adopt Industry 4.0 technologies (Dal Forno et al., 2023), with a lack of qualified workers identified as a key barrier (Monteiro et al., 2024). It is therefore important to establish whether the growth of the industry has been driven mainly by the expansion of capacity and employment or by rising productivity, and what role human capital and technology can play in shifting it towards a more intensive path.

The aim of this study is to assess the contribution of labour productivity growth to the growth of output in the textile industry of Uzbekistan in 2017–2025 and to determine how human capital development and technological innovation can strengthen this contribution. The objectives are to review theoretical and empirical research on the links between human capital, technology and productivity; to estimate the dynamics of output, employment and output per employee by product group; to decompose output growth into employment and productivity components; to analyse indicators of human capital and innovation; and to formulate recommendations. The object of the study is the textile industry of Uzbekistan, and its subject is the relationship between human capital, technological innovation and labour productivity in the industry. The study tests the hypothesis that productivity gains have been concentrated in downstream segments that received new equipment and new enterprises, while growth in upstream segments has been mainly extensive. The scientific novelty lies in the first product-level decomposition of textile output growth in Uzbekistan for 2017–2025, combined with an assessment of human capital and innovation indicators within a single analytical framework.

LITERATURE REVIEW

Research on the drivers of productivity growth that is relevant to this study can be grouped into four themes: the role of human capital in economic growth, the complementarity between technology and skills, experimental evidence from the textile and garment industry, and the specific conditions of technological change in textiles and in Uzbekistan.

The first theme originates in human capital theory, which treats education and training as investments that raise the productivity of workers and firms (Becker, 1993). Endogenous growth theory places the creation of new ideas at the centre of long-run growth and links it to the stock of human capital engaged in research (Romer, 1990). A different perspective was proposed by Nelson and Phelps (1966), who argued that the main function of education is to accelerate the adoption and diffusion of technologies that already exist. Benhabib and Spiegel (1994) supported this view empirically, finding that human capital influences growth mainly through its effect on technology adoption rather than as a direct factor of production. For an industry that relies predominantly on imported equipment, as the Uzbek textile industry does, the adoption-oriented perspective of Nelson and Phelps is more relevant than models of frontier innovation, because the key question is how quickly enterprises learn to use technologies developed elsewhere.

Within this theme, later research shifted attention from the quantity of education to its quality. Hanushek and Woessmann (2008) showed that cognitive skills, measured by international test scores, explain differences in economic growth far better than years of schooling, and that expanding enrolment without improving learning outcomes yields limited economic returns. This distinction is important for transition economies that have rapidly increased access to education: the growth effect of human capital depends on whether graduates acquire skills that enterprises can use. The World

Bank's Human Capital Index operationalises this idea by adjusting expected years of schooling for learning outcomes (World Bank, 2020).

The second theme concerns the complementarity between technology, organisation and skills. Firm-level research has shown that information technology, decentralised work organisation and skilled labour reinforce one another, so that investment in technology yields the highest returns when accompanied by changes in organisation and skills (Bresnahan et al., 2002). Comparing multinational firms, Bloom et al. (2012) found that the productivity returns to information technology were higher in firms with stronger people management practices. Acemoglu and Restrepo (2019) emphasised that automation displaces workers from certain tasks but also creates new tasks that require new skills, so that the net effect of technology on productivity and employment depends on how quickly the workforce adapts. More recent evidence adds an important nuance: in a large study of customer support agents, access to a generative artificial intelligence assistant raised productivity by 15% on average, with the largest gains among less experienced workers (Brynjolfsson et al., 2025). Whereas earlier studies stressed that technology favours skilled workers, this finding suggests that well-designed digital tools can also transfer knowledge to novices, which is relevant for an industry with a large share of newly hired employees.

The third theme comprises experimental and quasi-experimental studies from the textile and garment industry, which make it possible to identify causal effects. In large Indian textile firms, the introduction of modern management practices raised productivity by 17% in the first year through better quality, higher efficiency and lower inventories (Bloom et al., 2013). In Indian garment factories, on-the-job soft skills training increased worker productivity by 13.5% and produced a net return of 256% for the employer (Adhvaryu et al., 2023). A randomised experiment among Egyptian rug producers showed that access to export markets improved product quality and technical efficiency through knowledge transferred from foreign buyers, pointing to learning-by-exporting as a channel of upgrading (Atkin et al., 2017). Firm-level panel data also indicate a productivity premium of 23% for a trained worker against a wage premium of 12% (Konings & Vanormelingen, 2015). Although these studies examine different channels — management, soft skills, export learning and formal training — they converge on one conclusion: intangible investments in people and practices can generate productivity gains comparable to or greater than those from new equipment.

A related strand of research examines how firms translate innovation into productivity. The model proposed by Crépon et al. (1998) describes a chain in which investment in research leads to product and process innovations, which in turn raise productivity; the strength of each link depends on the absorptive capacity of the firm. In traditional manufacturing industries, however, most innovation takes the form of acquiring new machinery and adapting organisational routines rather than formal research. Research on global value chains complements this view. Gereffi (1999) showed that apparel producers in East Asia upgraded by moving from simple assembly to full-package production and then to their own design and branding, and that this progression relied on learning from international buyers. Upgrading therefore requires not only equipment but also new organisational, design and marketing capabilities, which are forms of human capital.

The fourth theme concerns technological change in textiles and the specific context of Uzbekistan. A systematic review of 115 publications concluded that the textile and apparel sector is at an early stage of Industry 4.0 adoption, with efforts focused on computerisation and automation aimed at raising productivity and reducing costs (Dal Forno et al., 2023). A later review of applications in the clothing sector identified investment costs, a shortage of qualified workers and the need to change business models as the main barriers, noting stronger resistance to adoption in emerging economies (Monteiro et al., 2024). With regard to Uzbekistan, the World Bank (2025) documented the transformation of the cotton sector and the rapid growth of textile employment, and Movchan and Walter (2024) showed that intermediate goods, mainly yarn and fabrics, accounted for 66% of the country's textile exports in 2022, compared with a 68% share of consumer products in world textile trade. The OECD (2023) found that the digital uptake of Uzbek firms remained low and that a lack of digital skills was a major barrier to business digitalisation, while the World Bank's

Human Capital Index for Uzbekistan stood at 0.62 in 2020 (World Bank, 2020).

The review reveals a gap. International research provides strong evidence that human capital and technology jointly determine productivity, but studies of the Uzbek textile industry focus mainly on exports, investment and cluster development and rarely measure productivity at the level of product groups or link it to indicators of human capital and innovation. This study addresses the gap by combining a product-level decomposition of output growth with an analysis of human capital and innovation indicators, and by interpreting the results through the theory of complementarity between skills and technology.

METHODOLOGY

The study used a quantitative descriptive-analytical design based on secondary data. This design was chosen because firm-level microdata on textile enterprises in Uzbekistan were not publicly available, whereas industry and national statistics made it possible to compare output, employment and exports consistently over 2017–2025. The design also allowed the results to be reproduced from publicly accessible sources.

Data were collected from several sources. Physical output for 2017 and 2025 was taken for five product groups — processed cotton fibre, yarn, knitted fabric, woven fabric and garments — from data published by the industry association UzTextileProm (2026). Employment in the industry was taken for 2018 and 2024 from the World Bank (2025) and for 2025 from the official review of the industry's results (President of the Republic of Uzbekistan, 2025), which was also the source of the value of output and foreign investment in 2025. Textile exports were taken for 2018 and 2022 from Movchan and Walter (2024), for 2024 from Fibre2Fashion (2025) and for 2025 from the Government Portal of the Republic of Uzbekistan (2026). The regional structure of textile output was obtained from the State Committee of the Republic of Uzbekistan on Statistics (2021). Indicators of human capital included higher education coverage for 2014–2024 (Statistics Agency under the President of the Republic of Uzbekistan [Statistics Agency], 2025), the Human Capital Index (World Bank, 2020) and survey data on basic digital skills (Kursiv Media Uzbekistan, 2026). Indicators of innovation were taken from the Global Innovation Index (World Intellectual Property Organization [WIPO], 2026).

Labour productivity was measured as output per employee for each product group and as export value per employee:

$$LP_{i,t} = Q_{i,t} / L_t \,, \tag{1}$$

where $Q_{i,t}$ is the physical output of product group i in year t and L_t is the total employment in the industry. Growth was expressed as the multiple $G = X_{2025} / X_{base}$ and as the compound annual growth rate $CAGR = G^{1/n} - 1$, where n is the number of years. Because output equals employment multiplied by output per employee, the growth of output was decomposed as follows:

$$\ln G_Q = \ln G_L + \ln G_{LP} \,, \quad s_{LP} = \ln G_{LP} / \ln G_Q \times 100\%, \tag{2}$$

where G_Q, G_L and G_{LP} are the growth multiples of output, employment and output per employee, and s_{LP} is the share of output growth attributable to the growth of output per employee. The logarithmic form was used because it makes the components additive.

Three methodological assumptions were made explicit. First, employment data were available only for the industry as a whole, so output per employee reflected both productivity within product groups and the reallocation of workers between them. Second, output data referred to 2017 while the earliest employment figure referred to 2018; since employment grew rapidly during this period, employment in 2017 was unlikely to exceed that of 2018, and the estimated productivity contributions should therefore be interpreted as upper bounds. Third, export values were expressed in current US dollars and were not deflated. All calculations were performed in Python using the values reported in the cited sources, and the results were then compared with indicators of human capital and innovation and with the findings of previous research.

ANALYSIS AND RESULTS

All five product groups expanded between 2017 and 2025, but at markedly different rates (Table 1). Garments and knitted fabric grew fastest, while yarn and processed cotton fibre grew more slowly than employment, which increased 3.31 times between 2018 and 2025, or by 18.7% per year.

Table 1

Physical Output of the Textile Industry of Uzbekistan by Product Group, 2017 and 2025

Product group	Unit	2017	2025	Multiple	CAGR, %
Cotton fibre processed	thousand t	468	1,095	2.34	11.2
Share of cotton fibre processed	%	40	100	–	–
Yarn	thousand t	412	930	2.26	10.7
Knitted fabric	thousand t	72	368	5.11	22.6
Woven fabric	million m²	370	1,265	3.42	16.6
Garments	million pieces	452	3,460	7.65	29.0
Employment (2018 and 2025)	thousand people	188	623	3.31	18.7

Output per employee increased for three product groups and decreased for two (Table 2, Figure 1). For garments, output per employee more than doubled, and growth of output per employee accounted for 41.1% of the increase in output. For knitted fabric this share was 26.6%, and for woven fabric it was 2.5%. For yarn and processed cotton fibre, output per employee declined, so that output growth in these groups was entirely attributable to employment.

Table 2

Output per Employee and Contribution of Productivity to Output Growth

Indicator	Base year	2025	Multiple	Productivity share of output growth, %
Garments, pieces per employee	2,404	5,554	2.31	41.1
Knitted fabric, t per employee	0.383	0.591	1.54	26.6
Woven fabric, m² per employee	1,968	2,030	1.03	2.5
Cotton fibre processed, t per employee	2.49	1.76	0.71	–
Yarn, t per employee	2.19	1.49	0.68	–
Exports, US$ per employee (2018 and 2025)	6,915	4,173	0.60	–

Textile exports amounted to US$1.3 billion in 2018 and US$3.3 billion in 2022 (Movchan & Walter, 2024), US$2.9 billion in 2024 (Fibre2Fashion, 2025) and US$2.6 billion in 2025 (Government Portal of the Republic of Uzbekistan, 2026).

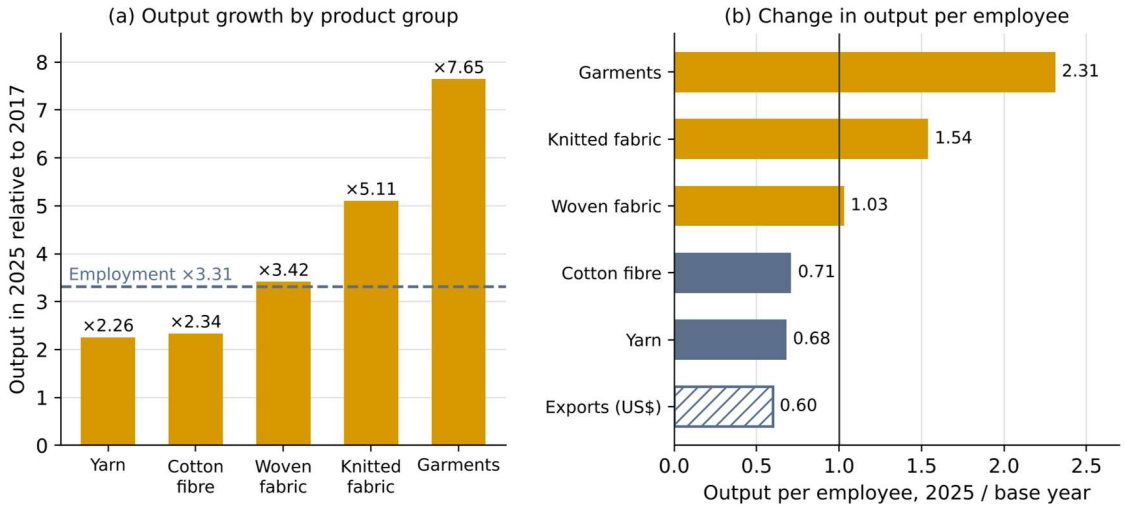


Figure 1. Output Growth and Output per Employee in the Textile Industry of Uzbekistan

Indicators of human capital and innovation are summarised in Table 3 and Figure 2. Higher education coverage of the population aged 18–23 increased from 6.8% in 2014 and 10.6% in 2018 to 47.7% in 2024. The Global Innovation Index rank improved from 93rd in 2020 to 77th in 2026, while research and development expenditure remained at 0.1% of GDP.

Table 3

Selected Indicators of Human Capital and Innovation in Uzbekistan

Indicator	Value	Source
Higher education coverage, ages 18–23	10.6% (2018); 47.7% (2024)	Statistics Agency (2025)
Human Capital Index	0.62 (2020)	World Bank (2020)
Expected vs learning-adjusted years of school	12 vs 9.1 years (2020)	World Bank (2020)
Employed people needing help to copy a file	39%	Kursiv Media Uzbekistan (2026)
Global Innovation Index rank	93rd (2020); 77th (2026)	WIPO (2026)
Human capital and research pillar rank	70th (2026)	WIPO (2026)
Research and development expenditure	0.1% of GDP (2024)	WIPO (2026)
Foreign investment utilised in the textile industry	US$2.1 billion (2025)	President of the Republic of Uzbekistan (2025)
Planned introduction of ERP and AI systems	40 enterprises (2026)	President of the Republic of Uzbekistan (2025)

The regional distribution of production was uneven. In the first quarter of 2021, the Fergana region accounted for 15.0% of the country's textile output, the largest share among the regions, followed by the Kashkadarya region with 9.8% (State Committee of the Republic of Uzbekistan on Statistics, 2021).

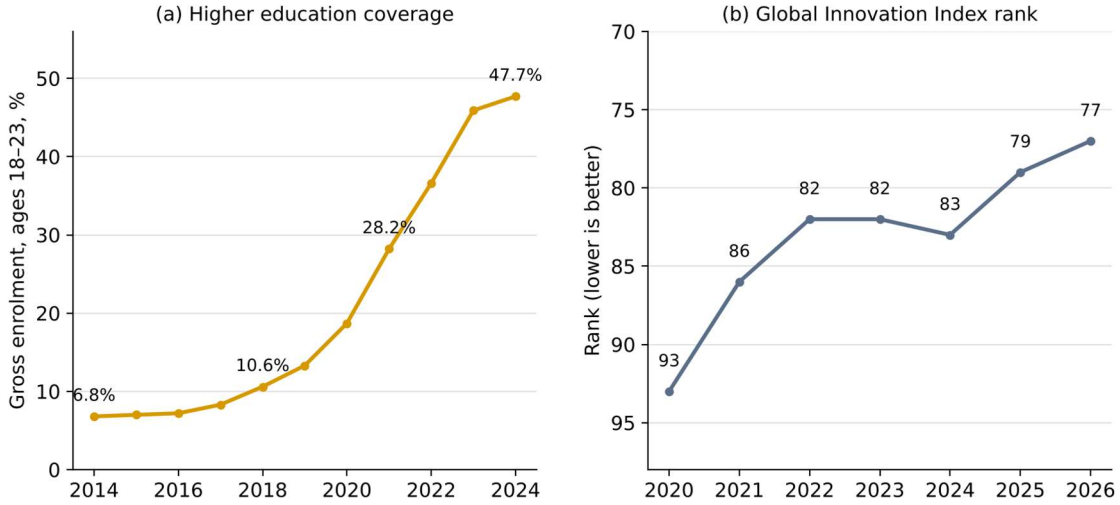


Figure 2. Higher Education Coverage and Global Innovation Index Rank of Uzbekistan

Export value per employee therefore declined from US$6,915 in 2018 to US$4,833 in 2024 and US$4,173 in 2025, a decrease of 39.6% over 2018–2025. The share of consumer products in textile exports increased from about 27% in 2018 to 34% in 2022 (Movchan & Walter, 2024). In 2024, exports of cotton yarn amounted to US$1,237 million and exports of ready-made textile products to US$1,124 million (Fibre2Fashion, 2025). The value of output per employee in 2025 was UZS 215.1 million.

DISCUSSION

The results answer the research question and largely confirm the hypothesis. At the level of the industry as a whole, growth in 2017–2025 was predominantly extensive: employment increased

faster than the output of yarn, processed cotton fibre and woven fabric, and only in garments and knitted fabric did output per employee rise substantially. Since employment data were available only for the industry as a whole, the decline in output per employee in upstream segments should not be interpreted as a fall in productivity in spinning. It more likely reflects the reallocation of labour towards garment production, which is far more labour-intensive. In this sense, the results document structural upgrading: the industry has shifted its workforce towards finished products, which is consistent with the rising share of consumer goods in exports observed by Movchan and Walter (2024).

At the same time, the decline in export value per employee indicates that physical expansion has not yet been converted into greater value capture. Several explanations are possible: the expansion of production for the domestic market, the predominance of basic, price-sensitive products, and the concentration of exports in a limited number of markets. The finding that yarn still exceeded ready-made products in exports in 2024 shows that the transition towards finished goods remains incomplete. The experimental evidence of Atkin et al. (2017) suggests that exporting to demanding buyers can itself be a source of learning and quality upgrading, which implies that diversification of export markets is not only a commercial objective but also a channel for acquiring technological and managerial knowledge.

The pattern observed in Uzbekistan can be interpreted through the stages of upgrading in apparel value chains described by Gereffi (1999). Moving from cotton fibre to yarn and then to garments corresponds to the first steps of this progression, from supplying raw materials to manufacturing finished products. The subsequent stages — full-package production, own design and own brands — depend much less on additional capacity and much more on capabilities in product development, quality management, logistics and marketing. These capabilities are embodied in people rather than in machines, so that the next phase of upgrading will be determined primarily by the development of human capital at the managerial and engineering levels.

The indicators of human capital reveal an apparent paradox. Higher education coverage increased by 37.1 percentage points between 2018 and 2024, yet the government identified a shortage of qualified specialists in the industry, and survey data show that a substantial share of employed people lack basic digital skills (Kursiv Media Uzbekistan, 2026). This combination suggests a gap between the quantity of education and its quality and relevance to industrial needs. The Human Capital Index points in the same direction: in 2020 the expected 12 years of schooling corresponded to only 9.1 learning-adjusted years (World Bank, 2020). This is consistent with the argument of Hanushek and Woessmann (2008) that the economic returns to education depend on the skills actually acquired rather than on enrolment. In terms of the adoption-oriented view of Nelson and Phelps (1966) and the evidence of Benhabib and Spiegel (1994), what matters for the textile industry is not the general level of educational attainment but the capacity of operators, technicians and engineers to master imported equipment and new production methods. Vocational and on-the-job training aligned with the needs of enterprises may therefore yield higher returns for the industry than further expansion of general higher education.

The results also illustrate the complementarity between technology and skills described by Bresnahan et al. (2002) and Bloom et al. (2012). The productivity gains observed in garments and knitted fabric coincided with large investments in new capacity, which suggests that they have so far been driven mainly by technology embodied in new equipment and new enterprises. The next stage of growth will increasingly depend on disembodied improvements — management practices, work organisation and workforce skills. The experimental studies reviewed above indicate that such improvements can raise productivity by 13.5–17% within a short period (Adhvaryu et al., 2023; Bloom et al., 2013). The planned introduction of enterprise resource planning systems and artificial intelligence technologies at 40 enterprises (President of the Republic of Uzbekistan, 2025) will generate returns only if employees have the necessary digital skills, which the OECD (2023) identified as a key constraint. The finding of Brynjolfsson et al. (2025) that digital assistants benefit less experienced workers most is encouraging for an industry with a young and recently hired

workforce, but it presupposes basic digital literacy.

The innovation indicators show progress but also structural weakness. The improvement in the Global Innovation Index rank reflects reforms in the business environment and institutions, but research and development spending of 0.1% of GDP indicates that domestic capacity for generating new technologies remains limited. For the textile industry, innovation will therefore take mainly the form of adoption and incremental process improvement rather than frontier research, which is consistent with the conclusion of Dal Forno et al. (2023) that the sector focuses on automation and efficiency. In the terms of Crépon et al. (1998), the weak link in the Uzbek textile industry lies not in the transformation of innovation into productivity but in the capacity of enterprises to absorb and adapt external technologies. This places a premium on cooperation between enterprises, technical universities and vocational colleges, particularly in regions with a high concentration of textile production.

The regional dimension deserves particular attention. Since the Fergana region has accounted for the largest share of the country's textile output, productivity gains in the region's enterprises would have a disproportionate effect on the industry as a whole. The concentration of textile enterprises, technical universities and vocational colleges in one region creates favourable conditions for joint training laboratories, practice-based programmes for engineers and technologists, and the dissemination of good management practices among small and medium-sized enterprises. A regional approach would also make it easier to monitor productivity and skills indicators and to evaluate the effect of specific programmes.

These findings have practical implications. Policy support for the industry, which has so far focused on capacity, investment and exports, should be complemented by instruments aimed at productivity: industry-specific skills programmes developed jointly with enterprises, management training for line supervisors and managers, the linking of preferential equipment financing to commitments to train staff, and the regular monitoring of productivity indicators at the enterprise level. Diversification of exports towards markets with high quality requirements would simultaneously support learning and value capture.

The study has several limitations. It relied on aggregated secondary data, and employment was not available by product group, so the estimates combine productivity changes with the reallocation of labour. The base years for output and employment differed by one year, which makes the productivity contributions upper-bound estimates. Export values were nominal, and part of the data came from an industry association. Finally, the descriptive design does not allow causal effects of human capital and innovation on productivity to be identified. Future research should use enterprise-level panel data and surveys, including in the Fergana region, to estimate these effects directly.

CONCLUSION

The study set out to assess whether the rapid growth of Uzbekistan's textile industry in 2017–2025 was driven by productivity or by the expansion of capacity and employment. The answer is that growth was predominantly extensive. Employment more than tripled, and only in garments and knitted fabric did output per employee rise substantially, accounting for about two-fifths and one quarter of output growth respectively. Output per employee in upstream segments and export value per employee declined, indicating that structural upgrading towards finished goods has not yet been matched by higher value capture.

Human capital and innovation indicators show substantial quantitative progress, including the rapid expansion of higher education and an improved innovation ranking, but also gaps in the quality and relevance of skills, in basic digital literacy and in domestic research capacity. The contribution of the study lies in a product-level decomposition of textile output growth and in an interpretation of the results through the complementarity between skills and technology.

To make growth more intensive, the industry and government should shift the emphasis from expanding capacity to raising productivity. Priority measures include industry-specific vocational and

on-the-job training, management training, the development of digital skills alongside the introduction of digital systems, the linking of investment support to training commitments, cooperation between enterprises and technical universities, and diversification of exports towards demanding markets. Regions with a high concentration of textile production, such as Fergana, are the most suitable places to begin implementing these measures, because cooperation between enterprises and educational institutions there can produce effects for a large part of the industry.

The practical significance of the study lies in providing a simple and reproducible method for monitoring productivity by product group, which government bodies, industry associations and enterprises can apply as new data become available. Future research should estimate the causal effects of human capital and technology measures using enterprise-level data and surveys of employees and managers.

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