SIN-CHN SCIENTIFIC PRESS PTE.LTD.

*Sustainable Economies* 2025, 3(2), 1943.
https://doi.org/10.62617/se1943

Article

# Technological improvement and economic growth: Evidence from employment generation in micro, small, and medium-sized enterprises (MSMEs) in Bangladesh

**Li Qi[1], Mousumi Akter[1,*], Hero Rana Barua Mito[1], Md Shahriar Kabir Sajib[2], Ahnaf Aiman Abdi[2]**

[1] School of Business, Zhengzhou University, Zhengzhou 450001, China
[2] School of Computer Science and Artificial Intelligence, Zhengzhou University, Zhengzhou 450001, China
*** Corresponding author:** Mousumi Akter, moubdy@gmail.com

**CITATION**

Qi L, Akter M, Mito HRB, et al. Technological improvement and economic growth: Evidence from employment generation in micro, small, and medium-sized enterprises (MSMEs) in Bangladesh. Sustainable Economies. 2025; 3(2): 1943. https://doi.org/10.62617/se1943

**ARTICLE INFO**

Received: 24 March 2025
Accepted: 28 April 2025
Available online: 28 May 2025



**Abstract:** The contribution of technological changes to economic growth in Bangladesh through the channel of employment, with a special focus on the Micro, Small, and Medium-sized Enterprises (MSMEs) sector, is explored in this study. It examines how technological progress has helped Micro, Small, and Medium-Sized Enterprises increase productivity, access new markets, and generate new jobs through secondary data from the World Bank and Ministry of Foreign Affairs (MOFA). The analysis underlines the opportunities and challenges MSMEs face in implementing novelties in technology, including infrastructure, financial availability, and technical skills. Correlation between Gross domestic product (GDP) growth and technology adoption is found, meanwhile, the relationship between unemployment rates and technological innovation is found to be negative. While impressive government initiatives exist, a few obstacles exist to the broad diffusion of technologies at all levels, such as insufficient financial access and technological infrastructure. The study provides practical policy recommendations aimed at accelerating Bangladesh's long-term development objectives, resolving extant barriers, and encouraging technology-driven growth.

**Keywords:** technological improvement; economic development; employment generation; digital transformation; MSMEs; Bangladesh

## 1. Introduction

MSMEs are very important in the context of economic development in Bangladesh and thus also for employment generation. These enterprises form crucial and dynamic elements in the country's economy and act as a catalyst in the development of long-term, sustainable growth. According to official statistics, MSMEs play a major role in employment in Bangladesh and become very crucial for the encouragement of social growth and economic inclusion. In 2023, MSMEs employ 86% of all workers in the industry and comprise 25% of the GDP of the country. Qi et al. [1] and Chowdhury et al. [2] have elaborated on their importance in economic betterment and poverty reduction. Bangladesh has an economic growth strategy for MSMEs that is driven by innovation and technological advancement. This can facilitate technology development opportunities in increasing production and venturing into new markets, thereby providing employment opportunities. Bhattacharya et al. [3] adds that the focus on technological advancement involves aspects such as the use of digital technology, process automation, and product development innovation, which enhances the capability of MSMEs to be more competitive in both domestic and foreign markets. The government of Bangladesh has

been initiating various programs in recent times to enhance the absorptive capacity of MSMEs for newer technologies. These include initiatives on capacity enhancement, supportive regulations for digital transformation, and access to formal financial services. Despite these, most of the MSMEs are still facing issues in adopting new technologies concerning infrastructure availability, finance, and technical expertise due to a lack of resources and proper environment [4]. These are challenges that have further hindered the full realization of technological advancement by MSMEs in the cause of social and economic development. If Bangladesh is to realize quality economic growth, there is a need to focus on building and nurturing a cadre of technologically capable MSMEs supported by qualified professionals and innovative business models. These businesses hold utmost importance in ensuring the supply chains are robust, thereby increasing employment levels and making sure sustainable growth is achieved [5]. Within the context of this paper, the focus shall be on how MSMEs are currently working in the advancement of technology to further facilitate economic growth in Bangladesh by creating jobs. It also makes recommendations on how to overcome current obstacles and fortify MSMEs' place in the nation's developmental trajectory.

Economic growth is a long-term real income growth where income gains are part of the growth. As opposed to growth, which is primarily focused on change in the volume of goods and services gained by the individual reflected by the rise in his average income, economic development is characterized by structural and drastic change in the majority of the national economy's structures [6]. Thus, economic growth can be termed as an increase in the ability of the economy to produce products and services within a certain timeframe. It refers to the long-term expansion of the economy's productive capacity to meet the demands of society on an individual basis. The continuous improvement in the living standards is due to the sustained economic growth of the nation, which in turn increases employment and national income as well [7]. Economic growth is such a broad array of variables which ranges from the amount of physical capital to people and natural resources, social and political considerations, technical advancement, and innovation. This is stated by Gu et al. [8] when it is said that technological advancement is among the major movers of the economy since it encompasses the application of a variety of efficient practices and scientific methodologies as is represented in **Figure 1**. Technology is defined as the type and level of technical tools that a certain proportion of labor utilizes. Technology has also been termed "a body of knowledge, experience, and practices". Technology along with the interaction between the subsystems of generation, dissemination, and acceptance of technology meets real and perceived economic and social needs to some extent [9].

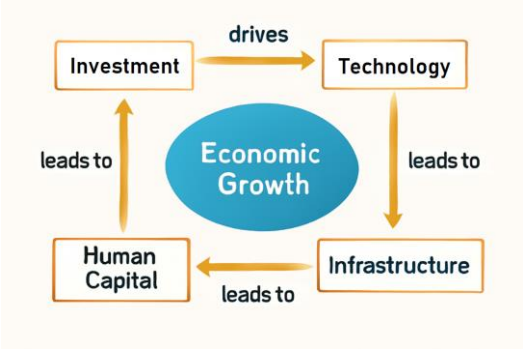


**Figure 1.** Factors affect economic growth.

In this study, Endogenous Growth Theory (EGT) and Innovation Diffusion Theory (IDT) are used to ascertain the relationship of technological progress to economic advancement among MSMEs. In terms of EGT, economic growth depends on human capital investment and knowledge, innovation, and knowledge-based growth [10]. The MSMEs in Bangladesh adopt new technology that assists in the enhancement of their production levels as well as in opening market spaces to aid GDP growth. These technological innovations also trigger employment opportunities by increasing operational effectiveness and enabling companies to scale up operations [11]. The importance of technology uptake in MSMEs in facilitating economic development and employment in developing economies. EGT confirms the argument that technological innovations play a critical role in sustainable economic development, especially in labor-intensive sectors like MSMEs. IDT was utilized to study the diffusion of technology among Micro, Small, and Medium Enterprises (MSMEs) in Bangladesh. IDT assumes that rates of adoption depend on perceived usefulness, compatibility with existing practices, and simplicity. Technology adoption is often hampered by lack of funds, inferior infrastructure, and absence of expert manpower [12]. Removal of these hindrances may capture huge growth opportunities. The study explores drivers of technology adoption by MSMEs, its impact on productivity, market competitiveness, and employment generation. Endogenous Growth Theory and IDT both have the potential to provide a robust analytical framework for understanding the role of technological innovations in stimulating economic and employment growth in the MSME sector.

## 1.1. Research objectives

This present study, therefore, focuses on creating jobs and economic growth by assessing how technological advancements have helped the growth of MSMEs in Bangladesh. This study focuses on assessing challenges faced by MSMEs in the implementation of technological innovations concerning financial availability, digital transformation, and infrastructure. It also seeks to discuss how financial ecosystems, collaborative models for innovation, and government policy can help MSMEs technologically grow to become competitive in both local and global markets. As already illustrated, technology needs to be in pace with GDP growth, with a decrease in unemployment rates. That is just an obvious correlation, though. This paper tries to move a little closer to an explanation by examining the relationship between

technology adoption and GDP, and also between technology adoption and the unemployment rate.

### 1.2. Research questions

The technological innovations cannot be overlooked while discussing increasing growth and productivity in MSMEs. The study explores those issues averted by the MSME towards adopting new technologies. In fact, it also defines the relationship between technology adoption and broader economic implications. In the Bangladesh context, understanding the ways innovations influence main economic factors is essential for the development of the economy. Guided by the following research questions:

1) How do technological changes bear on the productivity, market competitiveness, and adoption barriers of MSMEs in Bangladesh?

2) How do GDP and technology adoption relate to each other?

3) What is the relation between the rate of unemployment and technological adoption?

### 1.3. Research hypothesis

This research will develop important hypotheses that might investigate the relationship between technology adoption and important economic indicators in an effort to investigate the impact of technical breakthroughs on Bangladesh's economic development. However, this study tries to explore such predictions by focusing on how technology affects gross domestic product and unemployment rates. In this way, there is insight into ways where technological innovation might promote economic growth and address employment concerns. The following are the research hypotheses:

H1: Increased Research and Development (R&D) investment in MSMEs is positively associated with GDP growth in Bangladesh.

H2: Technological adoption in MSMEs is negatively associated with the national unemployment rate.

### 1.4. Research gap and contribution

This study assesses the effect of technology adoption among MSMEs in Bangladesh using longitudinal secondary data for the years 2019–2023. This study seeks to account for the causal link between technical innovations within MSMEs and GDP growth as well as employment creation over time, with a focus on the causal links between technology adoption and economic variables such as GDP growth and unemployment rates. Even with government efforts, MSMEs are experiencing obstacles in infrastructure, ease of finance, and technical capability, inhibiting them from realizing their full potential for economic growth and employment generation. Endogenous Growth Theory (EGT) and Innovation Diffusion Theory (IDT) are utilized in this study to examine the linkage between technological progress and economic growth in MSMEs in Bangladesh. EGT maintains that economic progress is spurred by technological innovation, human capital, and knowledge buildup, whereas IDT emphasizes the diffusion and take-up of new technology by businesses. The article explains the long-term effects of technology adoption on economic growth

and employment and recommends policy interventions to overcome technology adoption hurdles.

## 2. Literature review

This study will go through how technology affects GDP and employment in order to give important insights into the use of technology for accelerating economic growth and reducing unemployment. The present study has carried out a literature review pertinent to the subject in order to have a deeper understanding of published data related to the subject. Ayhan and Elal [13], have presented a significant amount of empirical evidence with respect to the relationship between technological innovation and employment. There seems to be no consensus, however, with respect to the nature and the extent of the relationship. While some empirical research has pointed out that technological innovation creates jobs [14], other studies have suggested that employment is negatively influenced by technological innovation [15]. Additionally, the influence of technology on employment has been ambiguous [16]. Some have asserted that the two factors bear no relation to each other at the macroeconomic level [17]. Asymmetries in the financial growth and income observed in the world economy may be basically viewed as the result of the unequal diffusion of technology. In turn, the object of technology is to enable individuals and organizations to use innovations better, decrease costs, enhance productivity, and consequently contribute to economic growth. In particular, new technologies provide countries with an opportunity to create more goods at a lower price; this allows them to build capital and develop a competitive edge in the international marketplace. It improves the quality of science research centers and leads to social and political development in most cultures accordingly [18]. The speed at which the economies are growing determines the quality of the innovations and the level of technical change. Technology is the backbone of corporate and industrial aims, and this is essentially very vital in developing manufacturing innovations and enhancing methods of production accordingly. This, in turn, engenders higher production volumes, better productivity, and higher profit margins, which are the essentials for growth and advancement in the economy of a country [19]. However, it is not sure that at all times and on every occasion, technical changes will have to lead to this end. Technical changes also have a differential impact on the fortunes of individual companies, industries, and even countries, depending on their level of application. Kyakulumbye and Pather [20], while conducting research on the subject, believe that information and communication technology, or ICT generally plays a constructive and fruitful role in the expansion of a business. ICT has been supportive of business organizational growth, mainly for communication through which businesses or organizations can share crucial data with an instant effect. In addition, ICT has enhanced the single-click information-gathering process [21]. ICT helps businesses cope with their output on schedule during the most crisis situations. Businesses using IT are more productive compared to other companies not using it. They grow faster and at times twice as much. Viewed financially, ICT-adopted businesses always reap higher profits [22]. The pandemic completely altered how firms approached “business survival.” During the pandemic, consumer focus moved to compatibility, and e-commerce adoption was still viewed to

have a high level of perceived complexity as observed by Billal Hossain et al., [23]. Such enterprises that have already adopted ICT are most likely to influence other enterprises to adopt the same compared to other organizations. Small businesses do not use ICT in their operations. Some of the reasons include inadequacy of information, low production, and perception of ICT as a sophisticated and unsafe instrument. The inability of SMEs to utilize ICT effectively is another reason according to [24]. Improvements in technology are considered an external aspect that has significant economic consequences.

On the whole, technology enhances production efficiency since it produces more goods using fewer inputs. Besides, innovation is normally inexpensive to adopt since it is easy to understand, communicate as well as apply across firms and nations [25]. Technological change has a major macroeconomic effect on the rate of economic growth as well as the return on the stock market. The fact that people in a society can adopt and integrate changes in technology into their daily lifestyle is another reason that fuels social development and makes technology strong for driving economic and social growth [26]. While successful economies can create more jobs abroad by exporting technology and information, such sectors demand skilled labor to match the ever-growing stride of technological growth. This further stress the need for a change in education policy to provide human resources that will lead to economic development. Technological innovation is among the most crucial aspects that raise a country's revenue and production capability at a fast pace [27]. It enhances efficiency besides economic wealth, which in turn gives nations or businesses a competitive edge in the global marketplace. Technology companies create increased productivity and global competitiveness because they are innovative leaders. Overall, technical development increases people's quality of life by being able to achieve goals that were previously unobtainable [28]. This increases wealth in nations' innovation and the resulting production capacity tends to have a very apparent positive relationship with GDP growth: the more innovative activity there is, the greater economic activity and liquidity are, as well as higher levels of international trade, all combining exponential growth in GDP [29]. The most important reason explaining the positive relationship between technological innovation and employment would be, that investments made in R&D, enable technological innovation to provide consumers with a broader range of new product varieties to choose from [30]. Therefore, this will drive up aggregate demand and eventually force the producers to raise output to meet the rising demand level. Increasing output by adding more workers to resolve the excess demand problem constitutes one of the most feasible solutions. Most producers hire more workers, thus decreasing the number of unemployed people, in response to this situation [31]. In that respect, this is another method through which technological innovation creates opportunities for employment through "product innovation" and, therefore, new jobs, as observed by [32]. Indeed, Nurillaev and Hiwatari [30] argued that product innovation added much value to job creation, particularly in industries with high and medium levels of technology. The employment influence of a type of technical innovation also differed based on the geographical region involved as well as the political system [33].

## 3. Research methodology and design

The study will use secondary data analysis and will draw from the World Bank, MOFA, and other related studies. Hence, this study seeks to gauge the effects of technical changes on job opportunities and economic growth in the MSME sector of Bangladesh from 2019 to 2023. In this aspect, the research study applies a descriptive and comparative methodology to test the hypotheses given herein for meeting the objectives of the research study and providing relevant answers to the research questions (see **Figure 2**). Extensive use of secondary data is obtained from reputed sources, such as government papers, World Bank and MOFA statistics, and previously published works. The research design used is a comparative study to assess the trend in MSMEs regarding the use of technology and its implication for GDP growth and unemployment rates. Other aspects analyzed in the research are the barriers to technology adoption, and it, therefore, focuses on significant elements related to the areas of technical know-how, infrastructure, and financial accessibility. Research and Development investment is a crucial indicator of technological adoption in MSMEs. It represents the commitment of MSMEs to enhancing their operational processes and advancing new technologies [34]. While R&D expenditure may not fully reflect technology adoption, it serves as a reliable proxy in Bangladesh, where data on adoption rates is limited. GDP growth and unemployment rates are conventional metrics used to assess the macroeconomic effects of technology adoption and MSME performance [35]. The research design explains how technological adoption relates to economic outcomes through secondary data analysis. It will also examine the adequacy of the initiatives taken by MSMEs and government policies toward developing technical innovation. It seeks to examine how technology development may result in productivity improvements, job creation opportunities, and economic growth for the long term in the MSME sector of Bangladesh, drawing on past trends and benchmarking worldwide where appropriate. Descriptive and comparative analyses are therefore adopted in the research methodology for a proper understanding of the role that technical changes can play in MSME-driven economic development.

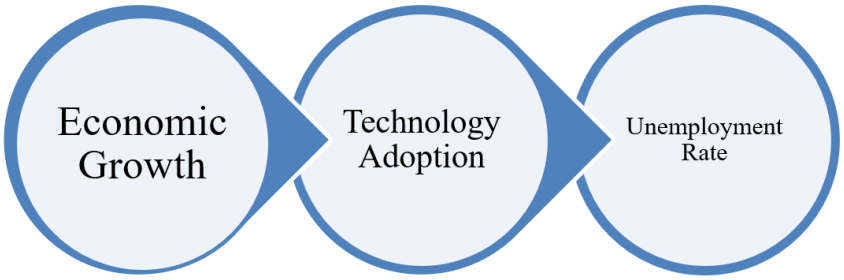


**Figure 2.** Model specification.

### Data collection

The collection of data for this research is based on secondary sources, ranging from 2019 to 2023. In this study, comprehensive and relevant data have been collected from a selection of key sources regarding the impact of technical enhancements on the MSME sector in Bangladesh. Key raw material: World Bank databases, and core macroeconomic indicators on technological transformation in the MSME sector,

including GDP growth rates, unemployment, and ICT exports. MOFA databases also allow for insight into investment patterns, the diffusion of technology, and the economic policies taken especially those to do with the adoption of better technology by MSMEs. The data is further enhanced by government publications in the form of national development plans and policy initiatives describing the government's investments and activities for promoting digital transformation within the industry.

The process of reviewing relevant scholarly literature also induced the development of a sound theoretical framework for the study. Such literature serves as a foundation for pertinent empirical research on links between employment, economic growth, and technology. These studies contextualize and support the analysis. GDP, GDP growth rate, unemployment rate, investment in R&D, and ICT export and export rate are some of the key economic indicators that this study concentrates on. This quantitative data describes how technological advancement and thereby, its economic implications are researched through descriptive and comparative methodologies (See **Table 1**). This, therefore, examines how the growth of GDP and employment within the MSME sector is and will be affected by the adoption of technology, hence giving insight into the general economic effects caused by technological advancements in Bangladesh.

**Table 1.** Economic indicators.

| Year | Investment in Research and Development (Taka) | GDP (USD-Billion) | GDP Growth Rate | Unemployment Rate | ICT Export (USD) | ICT Export Rate |
|---|---|---|---|---|---|---|
| 2019 | 100,000,000 | 351.23 | 7.9 | 4.693 | 511,501,279 | 8.2 |
| 2020 | 130,000,000 | 373.98 | 3.4 | 5.828 | 405,083,022 | 6.7 |
| 2021 | 137,500,000 | 416.27 | 6.9 | 5.815 | 618,499,208 | 8.3 |
| 2022 | 145,000,000 | 460.13 | 7.1 | 5.247 | 721,191,040 | 8.8 |
| 2023 | 145,000,000 | 437.42 | 5.8 | 5.060 | 636,693,363 | 10.0 |

## 4. Data analysis and discussion

The paper, therefore, tries to map the relationship between technological adoption and its impacts on economic growth and employment rates in Bangladesh within the MSME sector from 2019 to 2023. Technological adoption is proxied by investment in research and development. A clear trend thus crystallizes that denotes both the potential and the constraints of technical change in furthering economic development, as deduced from critical indicators like GDP growth, unemployment rates, and ICT export performance. This paper addresses the wider implications of the results and combines year-over-year comparative patterns.

### 4.1. Investment in research and development (R&D) as a proxy for technological adoption

R&D investment is considered one of the most important factors contributing to economic progress and technological development in many countries [36]. In Bangladesh, R&D significantly enhances the acceptance of new technologies that raise productivity and competitiveness levels in local and foreign markets; therefore, it is highly necessary for the MSME sector. R&D spending increased consistently from

Taka 1 billion to Taka 1.45 billion from 2019 to 2022, reflecting the government's commitment to firm up technological enhancements in key sectors of the economy. Investment in R&D involves much more than providing finance for science; rather, it is an investment in setting the base for technical innovation that fuels continued economic growth. Investment in R&D is critical in Bangladesh since MSMEs have been central to employment and economic growth in that country. Government-supported R&D programs often play a crucial role in enabling leapfrogging across the technological chasm due to a lack of resources and capabilities by MSMEs to develop appropriate solutions themselves. This is evidenced by the growth in spending for R&D from 2019 to 2022. It has shown that more and more legislators are becoming aware of the following: innovation driven by technical advances can be crucial to address domestic economic problems and compete worldwide. This is also the period when financing for R&D had been on the increase as one proactive strategy toward supporting technical upgrades to industrial processes, strengthening digital infrastructure, and enhancing the ability of MSMEs to adopt new technologies. These are all important elements in increasing overall competitiveness by reducing costs, improving efficiency, and enhancing overall performance. More often, the spillovers of new technology adoptions go beyond the individual business; instead, they flood into the general economy in the form of export growth, job creation, and shock resilience [37]. R&D investment is expected to grow by 45% over the coming four years from Taka 1 billion in 2019 to Taka 1.45 billion in 2022. This steady growth constitutes something quite remarkable, mainly because it means that the country now has a government committed to fostering innovation, technological uptake, and economic modernization. This more so represents understanding that in a rapidly changing world from a technological perspective, only continued or increasing R&D expenditure can be willingly accepted as important for economic competitiveness. Government-backed R&D is important to MSMEs faced with low resources and cannot afford the tools, technology, and expertise needed for their development [38].

## 4.2. The 2023 plateau: A strategic pause or absorption limit?

While it was consistently on an upswing from 2019 to 2022, the flatlining in 2023 at Taka 1.45 billion brings up a few pretty difficult issues concerning why this has happened. It very well may be a stoppage made from cognizance with respect to the back by which the public authority evaluates the consequences of prior speculations prior to giving any serious financing. Alternatively, this can be due to the fact that the absorptive capacity of the MSMEs, i.e., the ability to use and exploit new technology effectively, reached a temporary limit. Smaller enterprises, in particular, often experience far more obstacles to adoption than large ones, impeded as they may be by things like insufficient infrastructure, a lack of technical expertise, or access to funding. This may be so with MSMEs, as mentioned by [39]. After all, an increase in R&D funding will not automatically show prompt technological diffusion if these costs do not appear at the same time. Moreover, there may be a correlation between the 2023 flatline and general economic concerns. This may be because the government, in the post-pandemic process of recovery, with increased inflationary tendencies and distortions in the global economy, had to divert funds to address more urgent needs. Preoccupation with short-term issues of inflation control or immediate

economic recovery must have overtaken the urgency for investing in R&D, even as technical change is part of the long-term trajectory of economic growth [40]. The COVID-19 pandemic disrupted global and domestic economies, affecting financial flows, supply chains, and business investments. In 2023, inflationary pressures and increased business costs may have diverted resources away from R&D investment. In Bangladesh, the reduced absorptive capacity of MSMEs and strained fiscal environment may have led to a temporary pause in R&D investment momentum. Global supply chain disruptions and geopolitical tensions, including the war in Ukraine, may have further strained MSMEs' ability to invest in R&D [41].

### 4.3. R&D investment and its influence on GDP growth in Bangladesh

The technological adoption contribution to the economic recovery in the post-COVID-19 era is underpinned by the correlation between R&D investment and GDP growth in Bangladesh between 2019 and 2022. In 2019, for example, the expenditure on R&D was Taka 1 billion, while its GDP grew by 7.9%. However, the GDP growth fell drastically to 3.4%, even though R&D investment soared by 30% to Taka 1.3 billion in 2020. This steep fall was essentially due to the pandemic factor, which had affected the global supply chain badly and reduced consumer demand. It decouples the lessening growth in GDP and an increase in R&D expenditure, which suggests that, though important, R&D investment alone might not suffice to protect the economy against exogenous shocks, such as that of the pandemic.

GDP growth increased further to 6.9% in 2022, as R&D funding went up to Taka 1.45 billion and hit 7.1% in 2023, as the economy started recovering, while the R&D spending increased to Taka 1.375 billion. This implies that a mixture of new innovations, particularly by MSMEs, plays a basic role in upgrading efficiency, decreasing waste, and getting to new business sectors, among other jobs that have added to the recuperation of the economy. Be that as it may, notwithstanding reliable research and development spending, gross domestic product development in 2023 decelerated to 5.8%. This indicates that, along with technology and R&D-driven factors, general macroeconomic factors such as inflation, the scenario of the global market, and specific domestic issues have also been some of the key growth drivers. Flat R&D funding in this period suggests that, though the returns from earlier investments were coming through, money was not given greater priority as stated above, in view of the unhealthy economic environment. In 2022, Bangladesh's ICT exports reached their peak due to increased reliance on digital services and e-commerce during the pandemic. However, by 2023, the pandemic's effects waned and global demand for digital services normalized. Inflationary pressures, currency depreciation, and rising operational costs may have affected the cost competitiveness of ICT exports. Government policies, changes in export incentives, and global geopolitical tensions, including the Ukraine crisis, could have dampened demand for ICT services, especially from major buyers like the US and Europe [42].

### 4.4. The concept of development characteristics of technological improvement and its impact on MSMEs in Bangladesh

In recent years, especially, there has grown an increased interest in studying the contribution of MSMEs to economic development and employment generation in emerging countries like Bangladesh. Zou [43] and Taghizadeh et al. [44] are just some examples of scholars who talk about the role taken by technological advances in industrial upgrading and the enhancement of the operational efficiency of MSMEs. While Beltrame et al. [45] have explored the role of access to capital, which has been instrumental in enabling MSMEs to adopt newer technologies and expand their operations, Cunningham et al. [46] have thrown light on integrating digital technologies and innovation ecosystems to improve productivity amongst MSMEs. The "technologically upgraded" MSMEs focus on applying technology at a strategic level to enhance output and improve product quality thereby achieving a strategic advantage in the marketplace. These MSMEs are flexible and agile, hence they fill some of the gaps in the industrial value chain, especially in those segments or sectors where larger enterprises lack adequate specialization or flexibility. By paying attention to technological advances, these companies can better their position within the industrial chain and enable innovation and, at the same time, cooperation.

In Bangladesh, technologically advanced MSMEs have the potential to niche in markets and use technology to upgrade their manufacturing processes, digitize their operations, and manage their resources more efficiently [47]. Through their specialization, these businesses can narrow their focus into specific markets or industries, such as information technology, textiles, and agriculture, where they can apply the most advanced methods to meet the expectations of consumers. Refinement refers to the ability to enhance the quality control system by simplifying procedures using digital tools, which enhances effectiveness in management and rapid responses toward market demands. In the case of Bangladesh MSMEs, the uniqueness and novelty are so very important given the fact that this will facilitate an enterprise's adjustment to regional industrial clusters and the fulfillment of the specialized technological needs within the market. Innovation could bring in new product design, customized services for MSMEs, and an increasing industrial need for digital transformation. MSMEs have been basic supporters of financial improvement with regard to monetary development, work creation, and modern chain security. From the point of view of Bangladesh, mechanically improved MSMEs are not just expected to fill key holes in the modern production network but additionally act as drivers for more extensive monetary development. With a focus on the key components of the industrial chain, they are able to enhance local industries and encourage the integration of technological applications in supply chains for more resistance and efficiency. It is owing to this proactive approach that MSMEs can remain competitive in both local and foreign markets. Even though technologically enhanced MSMEs have brilliant prospects, most businesses in their own small ways face serious problems finding any capital, adequate technology infrastructure, and trained personnel. These issues create barriers to their capabilities for expansion of operations and making important innovations and breakthroughs [46]. In addition, super advanced information and human resources reliance include enormous ventures that are hard to access for private

companies since their admittance to channels of money is generally restricted. Resolving these issues calls for more noteworthy admittance to assets like money, specialized ability, and government-upheld programs inducing advancement and computerized change among MSMEs. Macroeconomic policies and supportive frameworks have a critical role to play in Bangladesh in fostering the growth of these enterprises and letting them evolve. By helping the growth of technologically advanced MSMEs, the country can create new opportunities for economic growth, industrial innovation, and full employment [48]. Along with this, it would ensure sustainable development of both urban and rural areas.

The expansion in research and development speculation reliably from 2019 to 2022 would be an essential chance for the MSME area, which comprises a significant lump of work and monetary exercises in the nation, Bangladesh, to upgrade the seriousness of the area. Research and development ventures would assist the MSMEs with scaling their activities, diminish reliance on human work, and extend market reach by working with the reception of advanced innovation, robotization, and development. This is especially significant in the present worldwide economy that is progressively advanced, where MSMEs should take on new advances to remain cutthroat. Additionally, interest in research and development can permit the MSMEs to broaden into new business sectors, extend their item portfolios, and investigate other new open doors in areas like ICT, which in the past has shown potential for development and, furthermore, demonstrated strong. If these gains are to be fully realized, the government has to eliminate the structural bottlenecks that deter the MSMEs from effectively exploiting innovations made through R&D efforts [49]. It would involve investment in worker training to build technical skills needed in technology adoption, expanding access to finance, and upgrading the digital infrastructure.

### 4.5. Unemployment rates and technological adoption

Technological changes have also been widely influential in employment trends, as reflected in increased R&D expenditure. It was seen that because of the financial impact of the pandemic, joblessness rates flooded suddenly in the year 2020 from 4.693% in 2019 to 5.828% in 2020. Be that as it may, from 2021 onwards, with expanded innovative work use and a monetarily fortifying climate, the pace of joblessness began to recoil. In 2023, the pace of joblessness had contracted to 5.060%, a declaration of the drowsy recuperation of the work market. This perhaps would be understood to imply that with the adoption of technology, the creation of a position within the MSME sector has been taken care of. Due to embracing new developments, MSMEs expanded their efficiency and seriousness in the lookout, hence diminishing joblessness and adding to work creation inside the business market [46]. However, that unemployment in 2023 still stands higher compared to the pre-pandemic status may be proof that the maximum capacity for innovation adoption with respect to lowering unemployment is far from being achieved. Insufficient infrastructure, alongside inadequate financial resources and a shortage of technical expertise, is what hinders the overall integration of innovation, especially in private enterprises (see **Figure 3**).

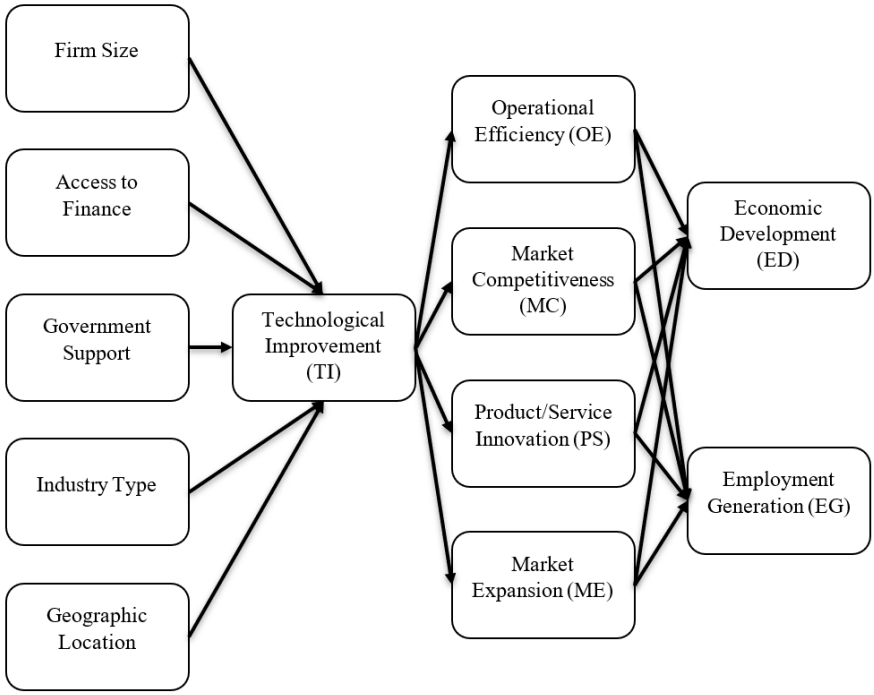


**Figure 3.** Technology adoption for employment.

### 4.6. ICT export and export rate trends

Other major areas of investigation include the success that the Bangladesh ICT sector is witnessing; more specifically, at what value and at what rate the ICTs are being exported. In 2019, the value of ICT exports stood at USD 511.5 million at an export rate of 8.2%. In the year 2020, the value sharply decreased to 405.08 million USD, while the ICT export rate also nosedived to 6.7%, showing the impact of the pandemic on the world economy. However, ICT exports started to increase in 2021 and reached their peak in the year 2022 at USD 721.19 million with an 8.8% export rate, showing the resurgence that meant Bangladesh's export potential was increased due to the ICT sector propelled by technological changes. In 2023, ICT exports decreased to USD 636.69 million, while the export rate increased as high as 10%. This would indicate that there is greater competitiveness, or efficiency, within the sector, even when there might be more general economic difficulties. This growing rate of ICT exports evidences the increasing importance of the industry in bolstering economic resilience and also points to how continuing technological investment is required to remain competitive on a global scale for ICT exports [50].

### 4.7. Correlation between R&D, GDP growth, and unemployment rates

This comparative research illustrates that GDP growth is highly related to unemployment rates and R&D spending. Generally, GDP growth continued to rise with increases in R&D spending, even with the significant recoveries witnessed in both 2021 and 2022. However, assuming that R&D spending remains constant, the growth of GDP slowed down in 2023, showing the downside of purely technology adoption without considering higher-order economic factors. Whereas technological changes contributed to a decline in the rate of unemployment, the fact that unemployment is still high compared to the pre-pandemic rate implies that more

measures are needed to reduce barriers to the adoption of new technologies in the MSME sector. The more grounded financial improvement time frames, for example, in 2021 and 2022, were joined by decreases in joblessness, further supporting the association of gross domestic product development with joblessness. That would go to say that new advancements assist with fostering the gross domestic product as well as fit for making positions and decreasing joblessness, particularly in innovation-driven ventures like MSMEs [51].

### 4.8. Bangladesh's current state of technological advancement

The need for more rapid technological development has been increasingly felt in Bangladesh. To be able to develop technologies within the country, and through the use of imported technology, scientific and technical research has been given much weight in the development objectives of Bangladesh. Since the country's dependence on imported technology is high, acceptance, assimilation, and acquisition of those technologies must be carefully planned [52]. Recently, the government has framed and approved a National Science and Technology Policy.

It sets standards for research, science and technology operations, institutional and human resource development, documentation facilities, and dissemination. It is through the National Council for Scientific and Technology (NCST) that scientific and technology policy reviews the work of several organizations, and provides direction for initiatives and research pertaining to science and technology [53]. The previous ones are the recent measures that have been taken by the government. Meanwhile, the educational system has not yet developed in a timely manner by providing teaching in science and technology to meet citizens' demands in the network era, furthering sustainable development through human resource development (see **Figure 4**).

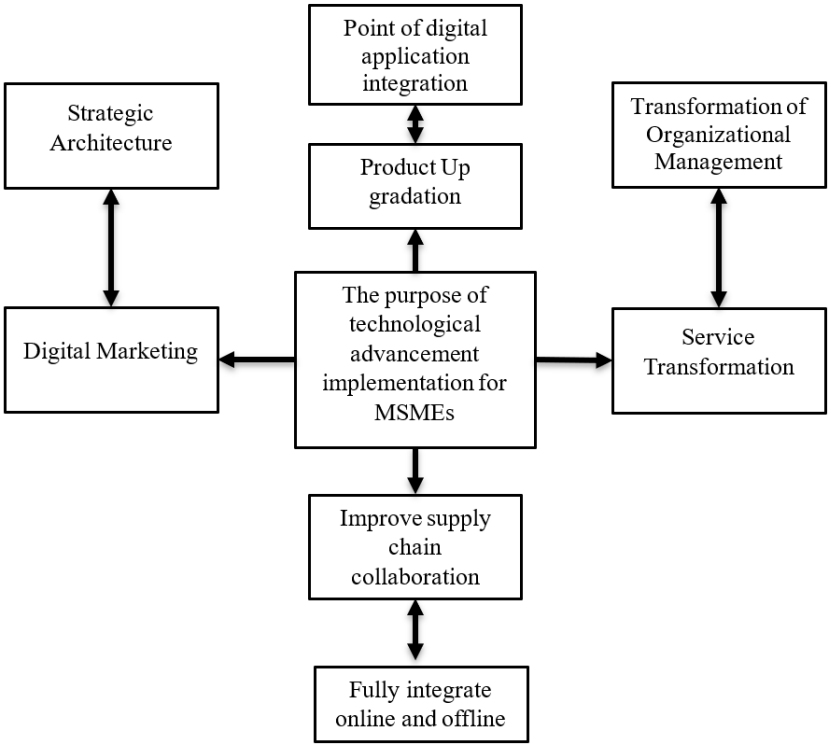


**Figure 4.** Technological advancement implementations for MSMEs.

### 4.9. The current development challenges of technological improvement in MSMEs in Bangladesh

Technologically intensive products along with the need for continuous innovation are also considered to be one of the significant determinants of growth in MSMEs in Bangladesh. These enterprises depend on their capabilities to adopt technological changes in their marketing strategies and manufacturing processes [54]. Such inventions demand deep knowledge of scientific and technological capabilities, as well as close linkage to both domestic and international markets and industrial value chains. MSME competitiveness in product development demands some predictive ability regarding market trends and technological developments. In fact, scientific and industrial knowledge acts as the main lever to innovation, market restructuring, and sustaining business growth. Despite the recent emphasis placed on digital transformation, MSMEs in Bangladesh face several barriers while adopting and using new technology. Even while technology spending is on the rise, MSMEs commonly face constraints in accessing finance, labor shortages, unsuitable technology infrastructure, and management techniques and skills gaps. Due to these challenges, many MSMEs experience difficulties in accepting new technologies and are hence either unwilling or poorly prepared for the same. The problem is that MSMEs sometimes try to adopt technologies that are not well thought out; the result is transformations that are less than satisfactory, or even wrong.

These development-related problems must be overcome if ever a breed of technologically capable MSMEs is to be developed that can thrive in an increasingly competitive industrial environment. These businesses need to focus on practical applications of technology and build their products around the needs of the particular industry in question, which requires focus and attention [46]. In Bangladesh, the ecosystem is still at a nascent stage in terms of technological application development in MSMEs and hence requires better access to finance technical capability, and market knowledge. The MSMEs of Bangladesh need an elongated and encouraging ecosystem of application of technology and innovation from an applicational point of view of industrial technology. The development of a robust "technology application and innovation ecosystem" is a further path to assist MSMEs in adopting new technologies across industries. It should be an ecosystem that focuses on solving industry-specific technological needs, facilitates collaboration between developers and business enterprises, and enables MSMEs to implement technology solutions scalable and flexible enough to respond effectively to changing market demands. A model of the "technology application and innovation ecosystem" might be provided in order to describe the current situation and problems regarding the future development of technological advancement in MSMEs. Based on fundamental technical concepts and tailored for vertical industries, such an approach would bring forth the key technologies necessary for MSME growth. Businesses can overcome obstacles related to the adoption of technology and secure a rightful place in the industrial value chain through customization of these models according to MSME needs, driving economic growth and employment opportunities in Bangladesh. The non-application of fundamental technologies, high establishment costs of independent R&D departments, constraints of small scale, and inability to attract first-class professional talent due to

resource constraints are some of the challenges for technologically advanced MSMEs in Bangladesh [55]. More often than not, MSMEs face the challenge of building technical service infrastructure that could support continuous innovation. It urgently needs to expand financing routes, increase funding for research and development, and bring in outside resources. Added to this, Bangladesh's current public technology service platforms still lack several essential tools required by the diverse needs of MSMEs. The same indeed holds good for the overall non-accessibility to ordinary technologies necessary for bringing about more technology and making scientific research accessible towards useful business applications.

Only around a handful of MSMEs in Bangladesh are advanced in their digital integration, whereas more than 80% of the industries remain in an early phase of digital transformation, as posited by Mim et al., [56]. The main problems facing most MSMEs are the low level of technical capability, the high cost of integration between the upstream and downstream stages, and the very limited availability of feasible digital solutions. Among the internal issues that many businesses face are the lack of strategic fit between the actual applications of digital technology and business circumstances, integration challenges between online and offline activities, and management support not being strong enough. In addition, with a lack of capability related to digital operation and incomplete top-level design of digital strategy, MSMEs cannot comprehensively accomplish digital transformation. With inadequate internal mechanisms, MSMEs cannot establish and maintain the necessary digital infrastructure that enables them to compete in the ever-digitizing economy. One of the major impediments to overcome by MSMEs, in particular, related to technical innovations, is financing in Bangladesh. These kinds of businesses usually possess very minimal tangible assets with high start-up costs, making conventional credit models difficult for them to meet the qualifications. Most of the time, financial institutions do not have prior knowledge of the technologies these businesses are developing or the risks associated with them, which usually translates into insufficient support. The high dependence of MSMEs on human capital and R&D expenses, combined with the lack of collateral required for traditional credit, further reduces their ability to receive financing. Financial institutions need to develop new assessment and evaluation models that take into consideration the special characteristics of technology-driven MSMEs. The government has increasingly begun to recognize these challenges, and many measures are being taken for the implementation of financial and fiscal policies that would help in the growth of MSMEs with enhanced technology. However, the country has to establish market linkages improve the overall infrastructure for technical services, and create the right business environment that would stimulate scientific and technological innovation for it to fully exploit the potential of such enterprises.

What is needed is a system that integrates the government, enterprises, education and research institutions, and venture capital investors in one coherent development model. These should be motivated through a mechanism that supports supply chain collaboration, alliances for technology sharing, talent creation initiatives, and special funding for such specific purposes. This will assist in the formation of an enabling ecosystem for technical innovation and upward mobility in Bangladesh's MSME sector, which it fosters through coordination among those different stakeholders. This

will go toward helping small businesses overcome their financial and growth constraints and ensuring sustained economic growth. Furthermore, Bangladesh should adopt an integrated approach in order to analyze the complex interrelation of several factors, capital, and technology exploring how technical progress could trigger high-quality economic growth. MSMEs would consequently be able to make full use of their potential for national economic development and reduce dependence on a single sector by applying these factors in a multiplier effect with technical change. MSME cluster development in Bangladesh is still considered to be in its infancy due to a lack of formal models of cooperation and reproducible methods of promotion. While a few MSMEs have started collaborating with larger enterprises, such collaboration is often superficial and not developed at all. According to Mehjabeen and Khan [5], this seriously hampers integrated industrial cluster growth due to the inability of MSMEs to maintain even the technological or production demands of larger market participants. Additionally, MSMEs are spread over the whole country and, though attempts have been made to integrate them into official data, have not yet formed strong clusters that could lead to actual industrial development. This causes disruptions in the value chains within most industries, which acts as a bottleneck in the formation of industrial clusters and reduces the overall competitiveness of MSMEs.

The establishment of supportive ecosystems required for technological improvement and economic growth for MSMEs in Bangladesh involves a high-quality support structure in an organized format that can assure high-quality economic growth and facilitate support for technological improvement for MSME's operating business concerns in the Bangladesh economy. Access to local and foreign financial markets, governance structures in standardized format, diversified financing options, and incubation programs must be included. This would include harmonizing their activities with national policy directions and putting in place broad strategies that guarantee MSMEs focused attention at different levels of their development. It would also be relevant to develop the overall financial ecosystem and, more specifically, models of investment like science and technology credit and venture capital, which are tailored according to the specific needs of technology-driven MSMEs. Such models will unleash new channels of finance for such companies that hold the potential to lead their respective industries. The MSMEs can also be facilitated in long-term funding and their integration into the industry supply chains through an environmentally friendly and sustainable financial system. Public service platforms should also be developed to incentivize cooperation between the MSMEs, academia, research centers, and large enterprises. These will also promote resource sharing, information sharing, and innovative partnerships to break down technological barriers [5]. Bangladesh will create chain-leading enterprises that impart expertise and resources to smaller ones and mentor MSMEs in building their own symbiotic industrial ecosystems. This would make key talent, information, and technology more accessible and hence build a foundation for the long-term path toward innovation. Finally, the promotion of investment and finance through partnerships with technology parks, venture capital firms, and financial institutions will create an integrated system that MSMEs can leverage in debt financing, equity investment, and entrepreneurial incubation to support innovation for better economic growth.

# 5. Policy implication

## 5.1. Building a supportive ecosystem for technological improvement and economic growth of MSMEs in Bangladesh

In this regard, to achieve the aim of quality economic growth and technological enhancement, an MSME in Bangladesh requires a holistic and coherent support mechanism [57]. In fact, it should comprise access to domestic and foreign capital markets, governance structures, various alternatives for finance, and incubation initiatives. This would involve coordination of their activities with national policy directions while implementing holistic strategies to ensure that MSMEs are supported in focused ways at various stages of their development. Development of the financial ecosystem must be enhanced by the establishment of investment models suited to technology-driven MSMEs, such as science and technology credit and venture capital. The new models would provide avenues to those companies that have the potential to lead in their respective industries and can open new avenues of funding. The long-term funding and integration into the industry supply chain of MSMEs can also be made possible with the help of an environmentally friendly and sustainable financial system. In addition, public service platforms should also be established in order to cooperate with MSMEs, academia, research centers, and large-scale enterprises. These would be platforms where resource access, sharing of information, and partnerships related to innovation tear down technical barriers. Bangladesh can ensure that small-scale enterprises benefit from the expertise and resources of larger organizations by providing incentives for chain-leading companies to mentor MSMEs in developing linked industrial ecosystems of their own. Through this collaboration, vital talent, information, and technology would fall within reach, thus building a base for innovation in the long term [58]. Finally, investment and financing encouragement through partnerships with technology parks, outside investment firms, and financial institutions provides the comprehensive ecosystem MSMEs shall apply to access debt financing, equity investment, and entrepreneurial incubation that will spur innovation and better economic development.

## 5.2. Building the science, innovation, and finance (SIF) industry chain to empower MSMEs in the real economy

To empower MSMEs through the amalgamation of the latest financial technologies with very real economic activities, building a strong Science, Innovation, and Finance industrial chain is very important. Financial institutions can use big data, cloud computing, blockchain, IoT, and AI to offer intelligent and data-driven, scenario-based services catering to the needs of MSMEs. Correspondingly, with improved access to finance, such transformation will also ensure Bangladesh's improved capabilities in terms of better primary raw material, higher-scale machinery, and core technologies that would support MSMEs in their reduction of technological vulnerabilities along with the contribution to industry technology standards development [59]. Financial institutions should take full advantage of advanced information technologies to improve client acquisition and data management. This could be in the form of profiling the MSMEs based on their patented ideas, market

potential, and financial needs through advanced data analytics. Breaking down silos will imply better utilization of resources with minimal transaction costs. Putting together significant databases on MSMEs will also make for better communication between financial institutions and companies, hence making it easier for the latter to gain whatever financial services they may need in order to expand and innovate. The promotion of such sustained growth requires the integration of government, finance, industry, and technology into a robust SIF innovation industrial chain. The result will be that investment decisions, technological applications, and industrial policy will have much easier and deeper integration. It is suggested that financial institutions enhance their service skills by providing customized financing services and building long-term relationships with MSMEs. It can be ensured that financial institutions allow MSMEs to have the wherewithal to drive technical progress and contribute to economic growth spearhead the creation of jobs in the growing economy of Bangladesh by supporting firms in all stages of their life cycle and placing emphasis on innovation.

### 5.3. Establishing a digital expert service team to enhance computing power and drive MSME transformation

It is due to the fact that increased processing power can help reach an advantage related to supply chain collaboration, product creation, and production processes. The establishment of a Digital Expert Service Team will, therefore, be quite instrumental in ensuring that Bangladesh MSMEs embrace the digitization process to take full advantage of digital technologies such as blockchain, cloud computing, and 5G to gain a competitive advantage. The use of sophisticated/high-technology tools in operations would facilitate productivity, enhance the quality of the products of MSMEs, and enable them to go up the value chain. The establishment of a technical advisory board with the help of eminent experts should see to it that digital innovation is ushered in by study and application, thus opening the way for “digital ecological parks” and digital infrastructure to hasten technological progress [60]. Closing the digital divide would not compel MSMEs to use outdated technology. The Digital Expert Service Team is prepared to support any business that wants to make its most recent technologies available to the market, such as digital twins, low-code platforms, and high-throughput computers, enabling more specialized and effective business models. MSMEs can fulfill best practices and service system development with larger businesses and continuously improve corporate reputation and quality. Improvement in technology skills will facilitate the switching of MSMEs to new and future-ready technologies according to their needs and thereby come out from operational inefficiencies. Along with technological improvements, the promotion of green and sustainable development shall be one of the major objectives for the MSMEs. The digital technologies, financial innovations, and ESG framework shall facilitate the MSMEs to go towards Green Certification, Corporate Carbon Accounting, and Green Financing. This will be in an effort to reinforce their market positions and contribute towards superior economic development by making them prioritize environmentally sustainable operations through incentives like green guarantees and subsidy schemes. All combined, this digital transformation and sustainability with an integrated

approach would put MSMEs in Bangladesh in a strong position to lead in responsible growth and innovation.

### 5.4. Promoting special boards for technological innovation and clustering of MSMEs

To promote innovative MSMEs technologically, Bangladesh should encourage the development within the regional stock markets of special boards. These need to be crafted in accordance with international best practices. Such a board would offer selected technologically advanced MSMEs specialized support through financial policies, listing recommendations, and other customized services. This would give incentives and subsidies regionally to motivate MSMEs to integrate into these markets and efficiently link up with multi-level capital markets. This, in the long run, will ultimately give the MSMEs the needed financial impetus to grow and develop. Bangladesh can thus create awareness for innovative MSMEs and give them access to growth capital by emulating global models like special board initiatives in China. The promotion of participation by MSMEs through their experience in high-tech industries is indispensable in attracting capital and promoting industrial development. MSMEs can strengthen their positions in both local and global value chains through an "industrial integration" model. MSMEs can develop world-class technology clusters by fusing key core technologies like health and next-generation IT with upstream and downstream supply chains. The above will focus on applied fundamental research and innovative technology advancement, thereby achieving technological self-sufficiency that will surely allow the MSMEs to contribute immensely to the industrial foundation and economic progress of the country. In line with solving problems in the stock market, provincial and municipal information-sharing platforms should be established to speed up the listing process of technologically advanced MSMEs. The exchanges, intermediary institutions, and regulatory bodies should come together to make available pre-listing services that are clear, efficient, and at reasonable costs. Besides bringing together resources from top executives and national associations of listed companies, such a move would ensure adequate counseling for MSMEs in providing guidance throughout each step of the listing process. This strong support structure will, in turn, enable MSMEs to expand their financial bases, ensure easy access to capital markets, and attract high-tech industries, all factors that will definitely go a long way toward propelling Bangladesh's overall economic growth.

## 6. Conclusion

While innovation-driven development and digital transformation will remain accented, technological advancement has to be a critical catalyst in realizing quality economic growth for Bangladesh. The time has come when, in the face of a new wave of global technological revolutions and changes in industries, it is about time to use appropriately the base technologies comprising big data, cloud computing, blockchain, digital twins, IoT, AI, and sensor technologies. It is only by upgrading their capacity for technical innovation and accelerating digital transformation that Bangladesh will be able to realize new growth opportunities and raise the level of specialization and competitiveness of MSMEs. This should, therefore, be the guiding principle for

achieving new drivers of economic growth and the high-quality development of the economy of Bangladesh. The world economy is becoming increasingly unpredictable, and policy formulation to promote the expansion of MSMEs with improved technologies is very urgently needed in Bangladesh. That means driving new paradigms for the fusion of digital and physical worlds and encouraging the advancement of digital technology in catering to the particular needs of MSMEs. By reformulating the paradigm of technological innovation and economic development for MSMEs, the country will then be in a better position to implement the policies driven by science and technology and translate the results into practical business dividends that could underpin the resilience and competitiveness of MSMEs, at the same time enhancing the autonomy of the home economy toward steady, sustainable long-term growth.

### 6.1. Limitations

The study on MSMEs in Bangladesh has limitations, including reliance on secondary data from macro-level sources, a lack of firm-level granularity, and using R&D investment as a proxy for technological adoption. The short analysis period (2019–2023) may not fully capture the long-term effects of technological investments in the MSME sector, as the benefits may take several years to materialize.

### 6.2. Future research directions

Future research should use firm-level data to understand MSMEs' sectoral heterogeneity and technology adoption. Longitudinal analyses and qualitative methods can provide insights into the long-term effects of R&D investment on MSMEs' productivity and competitiveness. Policy evaluation studies can assess government initiatives supporting technological innovation, including financial support, infrastructure development, and skills training, to refine strategies for fostering adoption.

**Author contributions:** Conceived and designed the study, wrote the paper, and supervised the research, LQ; assisted in writing the paper and analyzed and interpreted the data, MA; contributed reagents, materials, analysis tools, and data collection, HRBM; was responsible for data collection and analysis, MSKS; assisted in design the paper and data processing, AAA. All authors have read and agreed to the published version of the manuscript.

**Conflict of interest:** The authors declare no conflicts of interest.

## References

1. Qi L, Mito HRB, Akter M. Social Enterprise Transformation and Its Effects on Socio-economic Development: A Comparative Case Study of Developed and Developing Countries. Journal of the Knowledge Economy; 2024.
2. Chowdhury A, Ratna TS, Akhter T, et al. Rise of inflation and formation of interest rate on loans in industrial sector: A VECM approach to assess the impact on total industrial production from evidence of Bangladesh. Heliyon. 2024; 10(3): e24976. doi: 10.1016/j.heliyon.2024.e24976
3. Bhattacharya S, Krishnan V, Mahajan V. Operationalizing technology improvements in product development decision-making. European Journal of Operational Research. 2003; 149(1): 102-130. doi: 10.1016/S0377-2217(02)00428-9

4. Kumar S, Goel U, Joshi P, et al. Factors affecting Information & Communication Technology (ICT) adoption among MSMEs. Journal of Open Innovation: Technology, Market, and Complexity. 2024; 10(1): 100205. doi: 10.1016/j.joitmc.2023.100205
5. Mehjabeen M, Khan SN. Motivating factors affecting formalization of small informal enterprises: Evidence from an emerging economy. Business Strategy & Development. 2024; 7(3). doi: 10.1002/bsd2.426
6. Haapanen L, Tapio P. Economic growth as phenomenon, institution and ideology: a qualitative content analysis of the 21st century growth critique. Journal of Cleaner Production. 2016; 112: 3492-3503. doi: 10.1016/j.jclepro.2015.10.024
7. Haque MA, Raza Shah SM, Arshad MU. Sustainable Economic Growth and FDI Inflow: A Comparative Panel Econometric Analysis of Low-Income and Middle-Income Nations. Sustainability. 2022; 14(21): 14321. doi: 10.3390/su142114321
8. Gu X, Badeeb RA, Ali S, et al. Nonlinear impact of natural resources and risk factors on the U.S. economic growth. Resources Policy. 2023; 82: 103570. doi: 10.1016/j.resourpol.2023.103570
9. Yu X, Xu S, Ashton M. Antecedents and outcomes of artificial intelligence adoption and application in the workplace: the socio-technical system theory perspective. Information Technology & People. 2022; 36(1): 454-474. doi: 10.1108/itp-04-2021-0254
10. Varona L, Gonzales JR. Human Development, Productivity, and Economic Growth. Journal of Human Development and Capabilities. 2025; 26(1): 33-58. doi: 10.1080/19452829.2024.2439947
11. Meng L, Qamruzzaman M, Adow AHE. Technological Adaption and Open Innovation in SMEs: An Strategic Assessment for Women-Owned SMEs Sustainability in Bangladesh. Sustainability. 2021; 13(5): 2942. doi: 10.3390/su13052942
12. Ahn H, Park E. For sustainable development in the transportation sector: Determinants of acceptance of sustainable transportation using the innovation diffusion theory and technology acceptance model. Sustainable Development. 2022; 30(5): 1169-1183. doi: 10.1002/sd.2309
13. Ayhan F, Elal O. The IMPACTS of technological change on employment: Evidence from OECD countries with panel data analysis. Technological Forecasting and Social Change. 2023; 190: 122439. doi: 10.1016/j.techfore.2023.122439
14. Li Y, Hu M, Zhao L. Study on the impact of industrial green development and technological innovation on employment structure. Frontiers in Earth Science. 2023; 11. doi: 10.3389/feart.2023.1115476
15. Arenas Díaz G, Guerrero AJ, Heijs J. The effects of product and process innovation on employment: a meta-regression analysis. Eurasian Business Review. 2024; 14(1): 35-68. doi: 10.1007/s40821-024-00259-6
16. Asravor RK, Sackey FG. Impact of Technology on Macro-Level Employment and the Workforce: What are the Implications for Job Creation and Job Destruction in Ghana? Social Indicators Research. 2023; 168(1-3): 207-225. doi: 10.1007/s11205-023-03109-6
17. Ferraresi T, Roventini A, Semmler W. Macroeconomic Regimes, Technological Shocks and Employment Dynamics. Jahrbücher für Nationalökonomie und Statistik. 2019; 239(4): 599-625. doi: 10.1515/jbnst-2018-0003
18. Coccia M. Why do nations produce science advances and new technology? Technology in Society. 2019; 59: 101124. doi: 10.1016/j.techsoc.2019.03.007
19. Khanna R, Sharma C. Do technological investments promote manufacturing productivity? A firm-level analysis for India. Economic Modelling. 2021; 105: 105672. doi: 10.1016/j.econmod.2021.105672
20. Kyakulumbye S, Pather S. Understanding ICT adoption amongst SMEs in Uganda: Towards a participatory design model to enhance technology diffusion. African Journal of Science, Technology, Innovation and Development. 2021; 14(1): 49-60. doi: 10.1080/20421338.2020.1802843
21. Pellegrina LD, Frazzoni S, Rotondi Z, et al. Does ICT adoption improve access to credit for small enterprises? Small Business Economics. 2016; 48(3): 657-679. doi: 10.1007/s11187-016-9794-x
22. Kyobe M. Investigating the key factors influencing ICT adoption in South Africa. Kyobe M, ed. Journal of Systems and Information Technology. 2011; 13(3): 255-267. doi: 10.1108/13287261111164844
23. Billal Hossain M, Wicaksono T, Dunay A, et al. E-commerce Adoption of Small and Medium-Sized Enterprises During COVID-19 Pandemic: Evidence from South Asian Countries. The Journal of Asian Finance, Economics and Business. 2022; 9(1): 291-0298. doi: 10.13106/jafeb.2022.vol9.no1.0291
24. Mushtaq R, Gull AA, Usman M. ICT adoption, innovation, and SMEs' access to finance. Telecommunications Policy. 2022; 46(3): 102275. doi: 10.1016/j.telpol.2021.102275
25. Heshmati A, Kumbhakar SC. A general model of technical change with an application to the OECD countries. Economics of Innovation and New Technology. 2013; 23(1): 25-48. doi: 10.1080/10438599.2013.805918

26. Mohamed MMA, Liu P, Nie G. Causality between Technological Innovation and Economic Growth: Evidence from the Economies of Developing Countries. Sustainability. 2022; 14(6): 3586. doi: 10.3390/su14063586
27. Yeo Y, Lee JD. Revitalizing the race between technology and education: Investigating the growth strategy for the knowledge-based economy based on a CGE analysis. Technology in Society. 2020; 62: 101295. doi: 10.1016/j.techsoc.2020.101295
28. Lim S. Embedding technological transformation: the welfare state and citizen attitudes toward technology. European Political Science Review. 2020; 12(1): 67-89. doi: 10.1017/s1755773919000341
29. Li L, Du L. Impact of natural resources, financial innovation, and policy robustness on economic growth: A study of China and India. Resources Policy. 2024; 93: 105080. doi: 10.1016/j.resourpol.2024.105080
30. Nurillaev K, Hiwatari M. Innovation and employment growth in developing countries: the role of market structure. Economics of Innovation and New Technology. 2024; 34(2): 302-320. doi: 10.1080/10438599.2024.2331196
31. Akay GH, Dogan C. The effect of labor supply changes on output: empirical evidence from US industries. Journal of Productivity Analysis. 2012; 39(2): 123-130. doi: 10.1007/s11123-012-0290-2
32. Zhang L, Tan R, Peng Q, et al. Product innovation based on the host gene and target gene recombination under the technological parasitism framework. Advanced Engineering Informatics. 2024; 59: 102341. doi: 10.1016/j.aei.2023.102341
33. Straccamore M, Loreto V, Gravino P. The geography of technological innovation dynamics. Scientific Reports. 2023; 13(1). doi: 10.1038/s41598-023-48342-8
34. Ali S, Muhammad H, Migliori S. R&D investment and SMEs performance: the role of capital structure decisions. EuroMed Journal of Business; 2024.
35. Ross AG, McGregor PG, Swales JK. Labour market dynamics in the era of technological advancements: The system-wide impacts of labour augmenting technological change. Technology in Society. 2024; 77: 102539. doi: 10.1016/j.techsoc.2024.102539
36. Dritsaki M, Dritsaki C. R&D Expenditures on Innovation: A Panel Cointegration Study of the E.U. Countries. Sustainability. 2023; 15(8): 6637. doi: 10.3390/su15086637
37. Cirillo V, Fanti L, Mina A, et al. New digital technologies and firm performance in the Italian economy. Industry and Innovation. 2022; 30(1): 159-188. doi: 10.1080/13662716.2022.2055999
38. Sun H, Yang X, Tang X, et al. How innovation funding leads enterprises to engage in research and development: Small and medium enterprises' perspective. Jahanger A, ed. PLOS ONE. 2023; 18(7): e0289166. doi: 10.1371/journal.pone.0289166
39. Díaz-Arancibia J, Hochstetter-Diez J, Bustamante-Mora A, et al. Navigating Digital Transformation and Technology Adoption: A Literature Review from Small and Medium-Sized Enterprises in Developing Countries. Sustainability. 2024; 16(14): 5946. doi: 10.3390/su16145946
40. Norton A, Sigfrid L, Antonio E, et al. Improving coherence of global research funding: Pandemic PACT. The Lancet. 2024; 403(10433): 1233. doi: 10.1016/S0140-6736(24)00452-5
41. Raihan S, Jonaed F, Ahmed MdT. Impact of Stimulus Packages on Business Recovery During the COVID-19 Pandemic in Bangladesh. Journal of South Asian Development. 2024; 19(2): 169-198. doi: 10.1177/09731741241240612
42. Cumming D, Johan S, Khan Z, et al. E-Commerce Policy and International Business. Management International Review. 2022; 63(1): 3-25. doi: 10.1007/s11575-022-00489-8
43. Zou T. Technological innovation promotes industrial upgrading: An analytical framework. Structural Change and Economic Dynamics. 2024; 70: 150-167. doi: 10.1016/j.strueco.2024.01.012
44. Taghizadeh SK, Nikbin D, Alam MMD, et al. Technological capabilities, open innovation and perceived operational performance in SMEs: the moderating role of environmental dynamism. Journal of Knowledge Management. 2020; 25(6): 1486-1507. doi: 10.1108/jkm-05-2020-0352
45. Beltrame F, Grassetti L, Bertinetti GS, et al. Relationship lending, access to credit and entrepreneurial orientation as cornerstones of venture financing. Journal of Small Business and Enterprise Development. 2022; 30(1): 4-29. doi: 10.1108/jsbed-07-2021-0281
46. Cunningham JA, Damij N, Modic D, et al. MSME technology adoption, entrepreneurial mindset and value creation: a configurational approach. The Journal of Technology Transfer. 2023; 48(5): 1574-1598. doi: 10.1007/s10961-023-10022-0
47. Hoque MdR, Saif ANM, AlBar AM, et al. Adoption of information and communication technology for development. Information Development. 2016; 32(4): 986-1000. doi: 10.1177/0266666915578202
48. Ali MM, Islam AM, Wise VJ. The Great Recession of 2008: Impact on the Bangladeshi economy and international business

implications. Thunderbird International Business Review. 2011; 53(2): 263-276. doi: 10.1002/tie.20405
49. Aggarwal A, Joshi N. MSMEs' innovation: a barrier approach. Journal of Small Business and Enterprise Development. 2024; 31(3): 552-573. doi: 10.1108/jsbed-07-2023-0304
50. Ghezelbash A, Liu J, Fahimifard SH, et al. Exploring the Influence of the Digital Economy on Energy, Economic, and Environmental Resilience: A Multinational Study across Varied Carbon Emission Groups. Sustainability. 2024; 16(7): 2993. doi: 10.3390/su16072993
51. Talla Fokam DND, Kamga BF, Nchofoung TN. Information and communication technologies and employment in developing countries: Effects and transmission channels. Telecommunications Policy. 2023; 47(8): 102597. doi: 10.1016/j.telpol.2023.102597
52. Kim B, Cho Y, Yang MG. Technology Acquisition Strategy: A Latecomer's Perspective on Integrating Component Suppliers With System Integrators. IEEE Transactions on Engineering Management. 2022; 69(6): 2572-2587. doi: 10.1109/tem.2019.2947698
53. Islam MN. Strengthening Technological Capability for Industrial Competitiveness in Bangladesh. Science, Technology and Society. 2001; 6(1): 133-158. doi: 10.1177/097172180100600106
54. Hossain MB, Dewan N, Senin AA, et al. Evaluating the utilization of technological factors to promote e-commerce adoption in small and medium enterprises. Electronic Commerce Research. 2023; 25(1): 349-368. doi: 10.1007/s10660-023-09692-7
55. Rahman M, Emon MdEH, Antor MH, et al. Identification and prioritization of barriers to Industry 4.0 adoption in the context of food and beverage industries of Bangladesh. Benchmarking: An International Journal. 2024; 32(2): 757-783. doi: 10.1108/bij-06-2023-0371
56. Mim IZ, Rayhan MdGS, Syduzzaman Md. Prospects and current scenario of industry 4.0 in Bangladeshi textile and apparel industry. Heliyon. 2024; 10(11): e32044. doi: 10.1016/j.heliyon.2024.e32044
57. North D, Smallbone D, Vickers I. Public sector support for innovating SMEs. Small Business Economics. 2001; 16(4): 303-317. doi: doi.org/10.1023/A:1011164801073
58. Hossain MD, Moon J, Kang HG, et al. Mapping the dynamics of knowledge base of innovations of R&D in Bangladesh: triple helix perspective. Scientometrics. 2011; 90(1): 57-83. doi: 10.1007/s11192-011-0507-6
59. Hossain M, Karunaratne N. Trade Liberalisation and Technical Efficiency: Evidence from Bangladesh Manufacturing Industries. Journal of Development Studies. 2004; 40(3): 87-114. doi: 10.1080/0022038042000213210
60. Kuratko DF, Goodale JC, Hornsby JS. Quality Practices for a Competitive Advantage in Smaller Firms. Journal of Small Business Management. 2001; 39(4): 293-311. doi: 10.1111/0447-2778.00027