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### Digital Technology and Manufacturing: Theoretical Underpinnings and Certain Evidence from India

<sup>1</sup> Dr. Pradeep Kumar B, <sup>2</sup> Ganga S

<sup>1</sup> Professor, Department of Economics, Maharaja's College (Government Autonomous College), Ernakulam, India

<sup>2</sup> Research Scholar, The Gandhigram Rural Institute (Deemed to be University), Gandhigram, Tamil Nadu, India

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Corresponding Author: Dr. Pradeep Kumar B

#### Abstract

Digital technology fosters innovation in many ways. There are three prominent ways through which technology, especially digital technology, can influence the manufacturing growth rate of an economy. The paper discusses these channels in detail. Apart from explaining the theoretical process behind digitalisation in influencing innovation, the paper also highlights the progress that India

has made over the years in the digitalisation of the economy. Since it is estimated that by 2030, one fifth of India's national income will be contributed by the digital economy it is very apparent that policy interventions need to be made to meet the challenges and opportunities thrown up by digitalisation in future.

**Keywords:** Digital Technology, Total Factor Productivity (TFP), India

#### Introduction

Indeed, it is quite apparent that digitalization that has been rampant in every field of economic and social activity, let alone manufacturing, thanks to unprecedented growth of Information Technology assisted changes, has become one of the key drivers of the growth of manufacturing sector in the world both in terms of quantity and quality. Digital technology and the process of digitalization have actually contributed to the upgrading of traditional manufacturing sector, helped to diversify it into newer areas of processing and marketing of products, thereby triggering not only the optimization of the use of available and accessible resources but also paving the way for overall enhancement of various sectors through a process of unleashing the hitherto unexplored linkage effects. Studies show that digital transformation of manufacturing in India has been positively associated with their performance (Singh, Sharma, & Dhir, 2021) [3].

There are three prominent ways through which technology, especially digital technology, can influence the manufacturing growth rate of an economy. These channels of influence are elaborated below:

#### 1. Innovation

Innovation is the key to the impact of technological progress on manufacturing growth. As we know, the vertical and horizontal expansion of the manufacturing sector invariably depends upon the pace with which innovation gets unfolded in the economy. Innovation can, of course, mean many things, such as innovation of new product, new process, newer type of marketing and advertisement, and even a new type of technology that eases and enhances the present work. However, innovation is not easy task to be undertaken by all; it can only be done by people with extra capabilities and entitlements. It is in this context the role of entrepreneur and innovation has been emphasised by Schumpeter.

Digital technology fosters innovation in many ways. The pace with which innovation happens can be and has been enhanced considerably with the help of digital technology. The success and acceptance of innovation of new products and process can be quickly comprehended, and feedback on the new things can be easily gathered using digital technology. These things used to take enormous time and space before digital technology became rampant in the world. Manufacturing struggled a lot to know how new things were accepted by the industry and potential customers. This perhaps took more 'time and space' of manufacturing in innovating new things and ideas, and adopting 'reverse' strategies if needed. To put in other words, the advent of digital technology breaks all so called constraints that manufacturing entrepreneurs have been facing in respect to 'time and space' in getting innovation done in a constructive and successful manner (Shi & Li, 2020) [7]. Gathering feedback

using digital technology has been able to convert the scope of innovation from 'standardised production' to what is often called 'personalized' or 'customized' production (Han & Zhu, 2022) <sup>[4]</sup>. Digital technology has made possible what is often referred to as 'open innovation'. Open innovation is a strategy used by business organization using them their both internal and external ideas and faculties to develop and market new technology and products. This mode of innovation does not believe in considering innovation as a closed affair; instead, it affirms the need of collaboration and idea sharing. Open innovation in its simplest form supports a permeable boundary and believes that ideas and capabilities must flow in and out of the manufacturing units. Companies create open platforms using digital technology which enable their buyers to share their ideas about how the products must be designed to suit to their changing interests. These platforms are virtually open, and no closed attempts have been made to make it the property for the company alone which makes it a collaborative attempt. A company can consider open innovation as method of obtaining more information externally to improve its own new products and processes. Since open innovation is a collaborative approach in innovation endeavours, many people and institutions like companies of all sizes and stages, research institutions, universities and colleges, government organizations, non-profit organizations, end users/potential consumers and society can participate and benefit from open innovation. Procter & Gamble (P & G) has been successfully using a renowned and well proven open mode innovation technique known as Connect plus Develop which helps corporations to navigate ideas and opinions from other external agents that would be pooled together by the company to develop new products in accordance with the changing habit and preference of the potential and existing customers. The collaborated inputs that the companies receive from different sources will be employed to design and redesign existing products fitting to the changing requirements of users. It has been proved that has been able to tap these opportunities, and the company has been able to enhance its productivity considerable. These things notwithstanding, the real worry lies whether this model could be replicated in other areas where competition has become very strife. Having narrated innovation especially open innovation in details, it is pertinent to raise the issue of resource allocation effect of digital technology.

## 2. The Resource Allocation Effect

It is indeed true that many firms especially newer ones with no experienced hands in control struggle a lot to optimize the resource allocation considering the future plans of the entities. This often makes them invariably incapable of scaling up their operations, and ultimately, they themselves make their own exit from the market, being overrun by their experienced competitors in the field. Many start-ups entering into the field with much self-proclaimed objectives leave the field within a short span of time owing to the problems they face in optimizing the allocation of resources like manpower, materials, and the like. It is here digital technology can be and has been a saviour for many firms. The real question is how digital technology does help firms in mitigating grave issues pertaining to the allocation of resources. Undoubtedly, the gathering and processing of real time data about the market (product market), materials and manpower (factor market), and the policy inputs of the

government in business matters has been made possible easier, quicker, and reliable by the use of the programmed software which of course enable firms to react to the market changes as quickly as possible, making it possible to comprehend the things as they roll out. This in fact creates a level playing field for all firms particularly inexperienced start-up to compete with their counterparts, let alone preventing exit from the market. It is important to employ tools like AI and Machine Learning to facilitate the management of human resources. Issues in supply chain can be easily processed and addressed using digital technology. Remote controlling and managing of resources have become very easy with the use of digital technology, and many managers of start-ups adopt the strategy of multi-tasking with the help of digital technology which not only improves the prospects of the company in many fields but also enables the managers to enhance their own skills that make them more promising.

Efficiency in production occurs in three areas: efficiency in resource allocation (allocative efficiency), efficiency in processing, and efficiency in marketing. Of the three, what matters more important is the resource allocation efficiency and its effect on outcome. Often it happens that misallocation and efficient allocation of factors of production lead to wastage and decline output and profit. Studies have shown that digital transformation has improved resource allocation in many corporations. The Total Factor Productivity (TFP) of corporations and thereby the economy as whole has improved considerably (Jiang & Li, 2024) <sup>[1]</sup>. Digital Financial Capability (DFC) has also been recognized as an important strategy to bring qualitative as well as quantitative change in entrepreneurial behaviours (Luo, Peng, & Zeng, 2021) <sup>[2]</sup>. Digital technology can help entrepreneurs in re-optimizing allocation of factors of production in manufacturing units. It can also optimize the procurement plans by way of collecting information on prices and availability of resources irrespective location remoteness. Using digital technology firms in cluster can easily pool together resources from different sources, and this will pave the way for the availability of resources at the possible least cost, creating enormous possibilities in enhancing the revenue of firms. Undoubtedly, this will reduce the cost of procurement or purchasing substantially, making the products more competitive even in international market. It underscores the fact that contrary what the trade theories postulate, competitive advantage in the international market can be brought about even by harnessing digital technology, and making unprecedented decline in the cost of production of commodities and services. With servicing becoming quite easy since the advent of digital technology, manufacturing sector is said to have moved away from just manufacturing to manufacturing + service.

## 3. Penetration Effect

Before we delve into the penetration effect, it is pertinent to discuss the traditional 'linkage effect' widely discussed in many economic models elaborating on how economies grow vertically and horizontally. Linkage effect of industry is best explained with the much celebrated 'input-output model'<sup>1</sup>

<sup>1</sup> Input-output (IO) model articles discuss a system for analysing the production and consumption of interdependent economic sectors, developed by Wassily Leontief.

where how firms help each other by providing input-output support is well explained (Mendoza, 2023) [6]. Taking inspiration from these models, economists suggest that for an economy to grow especially in the case of poor and capital scarce economies, what is needed is to invest in those industries and firms which do have much external connection with the other industries. Investing in such industries with more linkage effect would spur growth in all connected sectors, leading to quantum jump in the production of various sectors, not only in the sector where investment is done initially, but also in other related sectors. In short, investment will have more horizontal multiplier effect provided investment is made in sectors having more linkage effects. Linkage effect is of two types: Forward Linkage Effect and Backward Linkage Effect. Digital technology creates forward linkages by enabling new downstream industries that use digital products as inputs and backward linkages by stimulating the growth of upstream industries that provide digital services and components. For example, the rise of digital services drives demand for cloud infrastructure, cyber security, and data analytics, while the development of digital platforms allows for the growth of industries that use these platforms for their output, such as e-commerce and remote work services.

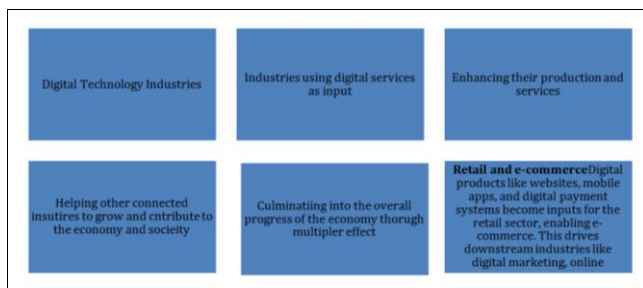


Fig 1: Forward Linkage

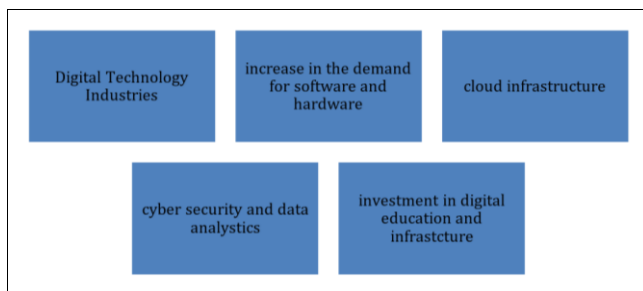


Fig 2: Backward Linkage Effect

### Forward Linkage Effect on Downstream Industries

A forward linkage is created when the output of one industry becomes a foundational input for another, driving new business activity and efficiency. In the digital economy, this means digital products, services, and infrastructure are used by other sectors.

### Examples of Digital Forward Linkages:

1. **Retail and E-commerce:** Digital tools like websites, mobile apps, and digital payment systems (the output of the tech industry) become the key input that allows the retail sector to launch e-commerce. This, in turn, fuels

growth in downstream services like digital marketing and online customer support, with companies like Alibaba as prime examples.

2. **Manufacturing and Smart Factories:** Technologies such as the Internet of Things (IoT), AI, and automation serve as inputs for manufacturing. This integration creates "smart factories" that can use real-time data for production planning and predictive maintenance, ultimately reducing manufacturing time and eliminating bottlenecks.
3. **Logistics and Supply Chain:** The use of IoT, Big Data analytics, and blockchain (digital inputs) enhances the efficiency of supply chain operations like delivery and after-sales service. Companies such as IKEA and Aramex leverage these digital platforms to optimize their logistics and delivery performance.

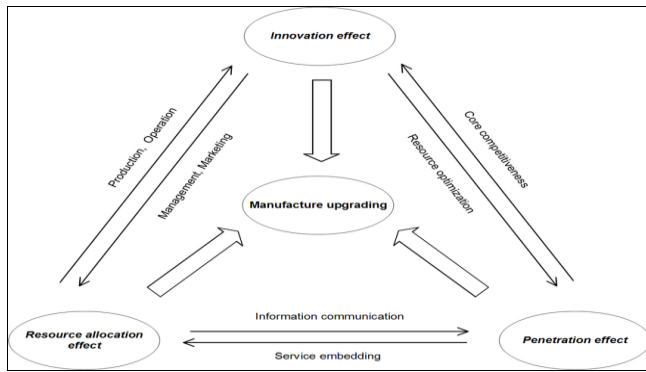
### Backward Linkage Effect: Upstreaming Industries

Backward linkages are created when the expansion of one industry increases demand for inputs from upstream industries. Digital technology stimulates the growth of upstream industries that provide the components, services, and infrastructure needed to create and support digital products. A backward linkage occurs when growth in a particular industry drives increased demand for inputs from its upstream suppliers. In the context of digital technology, the rapid expansion of digital products and services directly fuels the growth of industries that supply the necessary components. This includes:

- **Components and Hardware:** Manufacturers of microchips, sensors, data storage, and display screens for devices like smartphones and IoT systems.
- **Infrastructure:** Companies that provide the physical backbone, such as fiber optic cables, data centers, and telecommunications towers.
- **Specialized Services:** Providers of cloud computing services, specialized software tools, and advanced technical skills needed to develop and maintain digital platforms.

The "penetration effect" of digital technology refers to its widespread adoption and integration into society, leading to economic growth, increased productivity, and new entrepreneurial opportunities, but also contributing to potential issues like the digital divide and exacerbated income gaps. This integration fosters digital literacy, enables global innovation, and transforms traditional industries by introducing new factors of production, like data, but can negatively impact social and physical well-being if not managed responsibly.

In short, the interplay of three channels through which digital technology influences manufacturing growth can be modelled as follows. The innovation effect, resource allocation effect and penetration effect reinforces each other while their actions and reactions manifesting into upgrading of the manufacturing sector, leading to both quantitative and qualitative vertical and horizontal progress of the manufacturing sector. Now, we turn to some evidence to show how digital technology has become a vital factor in accelerating the growth of the manufacturing sector.



### Digital Economy Growth in India

Perhaps it is undeniable by any estimates that India digital economy has grown at much faster almost higher than the growth at which the real economy has grown over the last years. It is estimated that between 2014 and 2019, India's digital economy witnessed a growth rate which is 2.4 times faster than the growth rate shown by her real economy. In absolute terms, the size of the digital economy grew to \$222.5 billion in 2019 from \$107.7 billion in 2014. New sectors like agriculture, education, health, financial services and government services have been experiencing fast and unprecedented digitalization in recent times. Digital output multiplier also went up from 1.35 in 2014 to 1.52 in 2019. We know that India is the third largest start up eco system in the world after US and China. Of this, the growth Tech-Start-Up needs to be particularly noted. The number of Tech-Start-Up in India has increased by 12 to 15 percent during the period between 2014 and 2019. Out of around 21,000 Start-Ups, around 9,000 are Tech-Start-Ups. Economy wise digitalization has been one of the remarkable accomplishments that India has made in recent times. India is reported to have been the third largest digitalized economy in the world in the case of economy-wide digitalization. India's digital economy accounted for 11.74 percent of GDP in 2022-23 while employing 2.55 percent of workforce. It is estimated that the India's digital economy is five times more productive than the rest of the economy. Further, it is estimated that by 2029-30, one-fifth of India's national income will be contributed by her digital economy. Digital technology significantly drives manufacturing growth in India by improving efficiency, enabling Industry 4.0<sup>2</sup> adoption through technologies like AI, IoT, and robotics, and creating smart factories. This transformation is supported by initiatives like Digital India and government schemes such as the Production Linked Incentive (PLI) program, which encourage investment in advanced manufacturing. The increased use of digital tools boosts output, cuts costs, reduces downtime, and helps manufacturers adapt to market demands, positioning India

<sup>2</sup> Industry 1.0 (Late 18th Century) used steam power for mechanization, Industry 2.0 (Late 19th Century) introduced electricity for mass production, Industry 3.0 (Late 20th Century) brought computers and the internet for automation, and Industry 4.0 (Current) is characterized by smart factories integrating Artificial Intelligence (AI), Internet of Things (IoT), and cloud computing for connected, data-driven systems. Industry 5.0 implies the use of robots and personalized customization techniques.

for global leadership in the digital and manufacturing sectors.

### Industry 4.0

India stands at the forefront of a new industrial era driven by Industry 4.0<sup>3</sup> and rapid digital transformation. It's projected that digital technologies will account for 40% of total manufacturing expenditure by 2025 as compared to 20% of expenditure in 2021.

### Concluding Remarks

This paper has analysed the significance of innovation through digital technology in the field of India's manufacturing sector. It is obvious that in today's digital technology the process of innovation has been transformed in a big way. The paper has also discussed three ways through which digital technology can help the manufacturing sector in developing and revolutionizing the process of innovation. Apart from explaining the theoretical process behind digitalisation in influencing innovation process, the paper has also highlighted the progress that India has made over the years in the digitalisation of the economy. Since it is estimated that by 2030, one fifth of India's national income will be contributed by the digital economy it is very apparent that policy interventions need to be made to meet the challenges and opportunities thrown up by digitalisation in future.

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