# Impact of New Technology on Sustainability of Supply Chains: Empirical Evidence from Manufacturing SMEs in China

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**Abstract** New manufacturing technology can provide useful competitive advantages for enterprises to deal with fierce competition, and help them look for a better solution to production and operation management improving the quality of product services. New technology can also promote enterprises to obtain sustained economic, social and environmental benefits. This study, therefore, focuses on investigating the impact of technology on the sustainability of supply chains in small and medium enterprises (SMEs) in the Pearl River Delta region of China. The findings are based on 100 valid survey responses from SMEs in the region. The study identifies a set of enablers and barriers to new technology implementation in manufacturing SMEs. Our findings show that the economic factors occupy the central position whereas the market pressures from home and abroad; the vision of the enterprise's development; and the apparent advantages of new technologies were identified as other key enablers. On the contrary, the driving force from the government was found to be insufficient, whether it is a relatively free market regulatory environment or tax-free welfare policies for small businesses to promote the use of new technologies. The high production cost appears to be the most critical barrier followed by vicious competition among enterprises in the industry and lack of technical personnel. Our findings also show that enablers and barriers of new technology implementations are significantly correlated with sustainability performance measures (economic, social and environmental performance). Our study hence adds to the limited empirical literature focused on investigating the new technology and sustainability relationship.

**Keywords** SMEs · Technology · Sustainability · Supply chains · Empirical · Manufacturing

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## 1 Introduction

New technology in manufacturing industry refers to the technology used in the production process of enterprises, which can be applied to plan and control processes, manage information and actual production and assembly activities. In the context of rapidly changing market demand, everything needs to be fast and simplified. These advanced manufacturing technologies make the whole production process more systematic. The advantages lie in improving production speed and product service quality, increasing flexibility and reducing costs [1]. However, new technology means high investment costs or import costs, which makes many SMEs in developing countries stand back.

Nowadays, the new technologies used in the manufacturing industry can be divided into two categories: digital technology (the Internet of Things, cloud services, big data and analysis, blockchains) and new manufacturing technology (additive manufacturing, sensors, industrial robots, etc.). These digital technologies can automatically adjust the adaptive system of the production process for a variety of products and changing conditions [2]. Moreover, they can take into account information exchange and supply chain integration to reduce delivery time affected by the bullwhip effect and avoid information distortion [3]. Qrunfleh [4] suggested that by using the technology of information, the firms could manage commodity flow, information flow and capital flow. For example, blockchain facilitates valid and effective measurement of outcomes and performance of key supply chain processes through data transparency and information flow [5]. Robots with artificial intelligence can perform tasks more accurately in production and manufacturing than in the past, improve productivity, ensure early quality control and reduce production costs. Besides, Byrd and Davidson [6] pointed out that the long-term utilisation of information technology leads to better firm performance in terms of return on investment and market share.

Even though people's interest in sustainable issues is generally increasing, the current level of sustainable supply chain management practice is still limited [7]. Enterprises have begun to consider sustainability at the strategic level, but the current production model cannot be considered sustainable. Significant changes need to be made at the technical, managerial and organisational levels [8]. New technology can not only produce high-quality products but also improve the process of enterprise production and operation from a systematic point of view [9]. The high demand for economic and social development for supply chain performance promotes the use of technology in the supply chain. Tracey et al. [10] emphasised the consistency of technology and strategy and thought that new manufacturing technologies in alignment with strategy could differentiate firms from competitors and consequently can enhance their competitiveness. Yawar and Seuring [11] believed that the implementation of technology can not only promote the operation but also directly improve the ability of suppliers, thus improving their ability to deal with social problems.

From China National Bureau of Statistics, by the end of 2016, the number of SMEs in China was 370,000, accounting for 99% of the total number of enterprises, contributing 60% of GDP. Meanwhile, 347,000 SMEs are in the manufacturing industry (93.7%). SMEs in China have played a vital role in China's economic development. Compared with large enterprises, SMEs rely more on the workforce (ordinary workers rather than expertise), resulting in lower productivity, higher costs and lower constant delivery rate [12]. These disadvantages make it more difficult for SMEs to implement new technology development and improve their ability for sustainable development.

Existing studies show that most of the scholars discuss the supply chain strategy solely or the technology implementation separately. Besides, although the benefits of supply chain assessment for enterprise development has been clearly defined, few studies evaluate the supply chain performance in China. SMEs should adopt new technologies consistent with their supply chain development strategy to improve supply chain efficiency and strive to be guaranteed in economic, social and environmental aspects. However, the supply chain development level of SMEs in China and many developing countries and regions are still very elementary, and the utilisation rate of technology is meagre, which is not enough to support the strategic development of their supply chain. Therefore, the objective of this study is to find out the reasons that promote and hinder their use of new technologies to enhance their sustainable development capabilities. Therefore, it is more meaningful to discuss the drivers and barriers of new technology implementation faced by SMEs in China. It is also important to identify how can the use of these new technologies improve lasting economic, social and environmental supply chain performance.

## *1.1 Enablers of Technology Implementation*

The literature identifies several driving factors of technology implementation such as government, market, and social pressures. Luken and Van Rompaey [13] highlighted that when manufacturing industries adopt different technologies, the importance ranking of varying driving factors is different. Local policies set appropriate environmental standards for industries, and the quality of products and their impact on the environment have become the indicators of assessment [13]. Zhu and Sarkis [14] stated that regulations are still the most prevalent pressure for Chinese companies. Government-provided economic incentives for businesses, such as relaxed loan restrictions, grants, and tax exemptions [13], can further increase the adoption rate of new technologies.

The implementation of technology is also influenced by market factors. Kharlamov et al. [15] proposed that social responsibility, investor needs, government regulations and international standards, as well as customer awareness gradually force enterprises to pursue sustainable development. Similarly, these factors also promote the implementation of technology in the supply chain. Companies are facing challenging circumstances: markets are evolving; clients are becoming more and more

demanding and unpredictable; product variety is rising; time windows are shrinking, and error tolerance is decreasing. Therefore, technology implementation can solve these problems to some extent. Stakeholders, business partners, investors, primarily supply chain buyers, also impose environmental requirements on enterprises [16]. If the supply chain cannot be sustainable, enterprises will not be able to achieve sustainable development. Although some studies have improved the sustainability of products and services, the pressure from the supply chain is an urgent problem for enterprises to solve. For manufacturing enterprises with export business, entering international markets requires more stringent export product specifications than those produced at home [14], usually manifested in the fact that products are not allowed to contain certain chemicals. The changes in these markets, the needs of partners and customers will promote manufacturing enterprises to choose more technologies to implement production, to ensure the level of environmentally friendly development. Pressure from peers is also one of the social factors. Whether peers adopt relevant technologies has the value of being referenced by enterprises. If competitors can produce more publicly recognised products, it will threaten original company's market share, which means competitor will have higher profits, more significant market share and lower costs [17].

The other factor that also influences the technology adoption in enterprises is social pressure. The public attaches great importance to the environmental impact of manufacturing operations because it will affect their quality of life and environment. Local communities and media exposure will put pressure on manufacturers' factories. Additionally, as natural resources are becoming scarce, manufacturing enterprises that are heavily dependent on natural resources need to improve their technical capabilities and transform and upgrade. Besides, the ownership structure, size and internal capability of the factory are the main enablers to adopt technological means [13]. Enterprise strategy, long-term vision, values and culture, as well as the image and reputation of the company are all internal driving factors for the enterprise to choose technology for development and production [8]. Manufacturing enterprises have high production costs. Using technologies can accelerate the new product development process, reduce long-term production costs, reduce waste of resources and improve economic efficiency. Also, they can improve safety, especially product safety and personal safety of employees, which can meet the needs of employees [18]. The benefits of these technologies themselves drive enterprises to transform and upgrade, and use technology in production and operation.

## *1.2 Barriers/Challenges of Technology Implementation*

Although the role of technology in production and operation has been known, many enterprises do not intend to use new technology. The first kind of enterprises finds themselves unable to face new possibilities in controlling production and planning functions; It is the perceived (lack of) technological capabilities of firms that hinder them from adopting the technology. This idea is manifested in the lack of relevant

professionals and operational skills, even if appropriate technical resources have been obtained, some SMEs do not use new technologies in the actual production and operation. Moeuf et al. [12]. The second is the lack of intention to use technology to promote sustainable development. Leleux and Van der Kaaij [19] found that though many firms have the desire, the willingness or even the belief in the impact of sustainability on their businesses, they still failed to identify proper objectives for their efforts, which make them were unable to implement their sustainability strategies successfully.

SMEs also face many difficulties when introducing new technologies and system because of realistic limitation such as the significant initial investment, the burden of maintaining staff to operate it, and continuous payment of maintenance costs. In researching the reasons for the failure of SMEs in Malaysia, Arham et al. [20] also emphasises the influence of the behaviour of leaders and managers on the organisational performance of SMEs and indicates that managers need to show transformational and transactional leadership behaviour to retain talents. The support of senior managers who formulate and define strategies helps build long-term partnerships between supply chains [21]. Wang and Bi [22] stated that a single company could not achieve sustainable manufacturing but a system of enterprises in a global dimension, and proposed services based on cloud computing to tackle this challenge. When new technology products enter the market, most enterprises or individual consumers will take a wait-and-see attitude until more people adopt it. The high R&D costs of the technology itself cause some obstacles in the policy. The existing research shows that scholars have proposed a wide range of impetus and obstacles. However, only by defining the driving factors and challenges of implementing new technology to develop a supply chain for specific types of enterprises is not enough.

## *1.3 Sustainable Supply Chain Performance*

There is no consistent definition of the sustainable supply chain in the existing literature, partly because of the meaning of the supply chain and the demarcation of its boundaries [23]. The concept of a sustainable supply chain focuses on promoting the sustainable development of the supply chain at three levels: economy, environment and society. A majority of studies have advocated that organisational sustainability lies in economic, social and environmental performance. However, Gopal and Thakkar [24] stated that many enterprises focus on measuring lasting performance at the product or functional level, rather than on the sustainability of the entire supply chain and process. This study therefore will measure sustainability performance in these three directions, aiming at solving the economic, social and ecological problems of sustainable supply chain management.

From the economic dimension, sustainable performance improvement should be related to the control of corporate profits, investment and costs. As for the manufacturing industry, it means manufacturers' ability to mitigate procurement-related expenditure, cost produced by energy consumption, abandonment management and

fines due to environmental accidents. The innovation ability, total sales, the number of shareholders and the new employment opportunities created by companies are criteria to measure the sustainable economic performance of enterprises [25]. Sustainable profit is the guarantee of sustainable development of enterprises. Therefore, focusing on the durable economic performance of enterprises can help to obtain sustained growth of benefits and resources.

The society has the aspects of 'customers', 'employee', and 'community'. The indicator of social sustainability can focus on work conditions, societal commitment, customer issues, philanthropic contributions, the responsibility to the community; employee turnover rate, health and safety of local communities, equal opportunities and diversity, potential adverse side effect on or from secondary, stakeholders, stakeholders engagement satisfaction [26]. Enterprises have concentrated on the development of a responsible supply chain, and to the help of their products, services and behaviours to the harmonious development of society [27]. Only when enterprises enhance their social influence by improving their behaviour, consumers will generate additional trust in enterprises, and also enable enterprises to attract and retain talents.

Environmental performance relates to the ability of manufacturing plants to reduce air emissions, wastewater, solid waste and the consumption of harmful and toxic substances. Modern enterprises also need to make up for the damage caused by traditional enterprises to the environment, such as in all aspects of the supply chain, focusing on waste and pollution management, recovery and reuse of used products [22]. This kind of behaviour affects not only economic benefits but also environmental benefits. Enterprises that do not pay attention to environmental protection cannot enjoy long-term benefits. At the same time, these three kinds of performance are mutually reinforcing. Improving health, safety and environmental performance of manufacturing enterprises can increase revenue and market share, and promote flexibility, quality and responsiveness in business processes [16].

## *1.4 Research Gap*

When researching how the use of new technology can improve the sustainable performance of the supply chain, most scholars have studied in large multinational enterprises, because there are relatively few obstacles when large enterprises implement new technology. Saad et al. [28] highlighted that SMEs have a different set of challenges. It is evident from the discussions presented in earlier sections that SMEs have the disadvantage of not obtaining economies of scale, and their product portfolio is small. Sources are short and over-reliant on a single market and product. Compared with large enterprises, SMEs rely more on the workforce (ordinary workers rather than expertise), resulting in lower productivity, higher costs and lower constant delivery rate [12]. These disadvantages make it more difficult for SMEs to implement new technology development and improve their ability for sustainable development. So when more substantial companies can quickly produce similar products or provide better services, how to survive in the market and improve profits becomes the key.

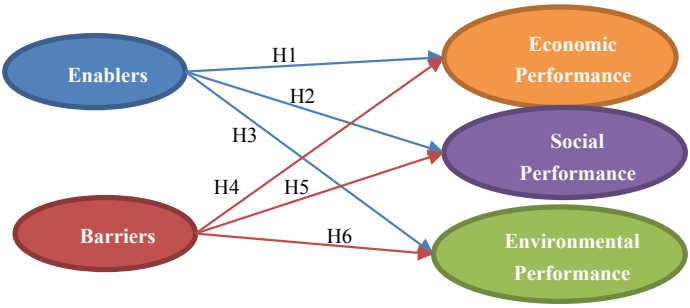


**Fig. 1** Conceptual framework

Although the benefits of supply chain assessment for enterprise development has been clearly defined, there is limited literature on the evaluation and optimisation of supply chain performance in China. SMEs should adopt new technologies consistent with their supply chain development strategy to improve supply chain efficiency and strive to be guaranteed in economic, social and environmental aspects. Also, the status quo of implementing new technologies and improving the supply chain in SMEs in China is different from that of large enterprises and SMEs in western developed countries. Therefore, it is more meaningful to discuss the drivers and barriers faced by SMEs in China. The conceptual framework encapsulating the discussion presented earlier is shown below in Fig. 1 together with a set of hypotheses that will be tested in this paper.

*H1: The evaluation score of the enablers is positively related to the assessment of the enterprises' economic sustainability performance*

*H2: The evaluation score of the enablers is positively related to the assessment of the enterprises' social sustainability performance.*

*H3: The evaluation score of the enablers is positively related to the assessment of the enterprises' environmental sustainability performance.*

*H4: The evaluation score of the barriers is negatively related to the assessment of the enterprises' economic sustainability performance.*

*H5: The evaluation score of the barriers is negatively related to the assessment of the enterprises' social sustainability performance.*

*H6: The evaluation score of the barriers is negatively related to the assessment of the enterprises' environmental sustainability performance.*

## 2 Methodology

This study adopts a survey-based approach. A survey tool was created and distributed to SMEs (employing less than 500 people) in the Pearl River Delta region of China. The Pearl River Delta has always been an essential position for China to carry out different economic activities and has a solid foundation in manufacturing. It includes nine cities in Guangdong Province: Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing. In recent years, the survival crisis of manufacturing industry in the Pearl River Delta has become increasingly prominent. Emerging manufacturing industry is continuously rising, so taking SMEs in this region as the research sample can increase the reliability and representativeness of the research. The questionnaires designed using Qualtrics software and are mostly matrix questions measured on five-point Likert scales. The survey data was analysed through SPSS using descriptive statistics, correlations and regression analyses. The study has followed the necessary ethical protocols in data collection and post-study data disposal.

## 3 Results and Discussions

The survey was distributed to more than 500 SMEs operating in the Pearl River Delta region of China. The survey resulted in 146 survey responses representing a response rate of 29.2%. However, careful evaluation of the data showed that 46 respondents did not fill out the full list of questions and quit the survey halfway, hence these responses were discarded for final analysis. Hence, the effective sample size is 100 respondents with a response rate was 20% which is well aligned with previous studies where an effective survey response between 20–30% is deemed acceptable.

The first part of the questionnaire was focused on collecting demographic information. Around 67% respondents employed less than 250 people whereas 33% respondents employed between 250–500 people. According to the position classification, among the respondents, there were 7 CEOs, 22 general managers, 21 senior managers, 42 general employees, and the remaining 8 included had other roles such as research and design director engineers, professional managers, project managers, etc.

The second part of the questions was focused on evaluating the enablers and barriers to the use of new technologies by SMEs. Table 1 shows the constructs and the measurement items used which were measured on a five-point Likert scale. Findings show that the most critical factor in the enabler is the pressure from competitors in domestic and foreign market competition, which had an average score of 4.02. Which was followed by the enterprise's vision of sustainable development (avg. score 3.90) urging SMEs to use new technologies in production activities. The vision of an enterprise influence the decision-making in its operation and its development vision and culture are strictly related to the willingness of its leaders. The third most important factor was the significant advantages of new technology (avg. score

**Table 1** Enablers and barriers of technology implementation in supply chains

| Constructs | Category | Code | Influence elements |
|---|---|---|---|
| Enablers of technology implementation in supply chain | Government | GOV1 | Policy support (loans/government grants/tax exemption) |
| | | GOV2 | Government's attention to production indicators and regulations |
| | Market | MAR1 | Pressure from partners (e.g. stakeholders) in the supply chain |
| | | MAR2 | Pressure from competitors (domestic and foreign market) |
| | | MAR3 | Quick market changes and large demand for products |
| | Society | SOC1 | Public demand for green manufacturing |
| | | SOC2 | Local environmental pollution is serious, shortage of natural resources and energy |
| | Internal motivations | INT1 | Vision promotion of Enterprise's self-development |
| | Technology | TEC1 | The obvious advantages of new technology |
| Barriers of technology implementation in supply chain | Lack of awareness | LOA1 | Lack of awareness of using new technologies |
| | | LOA2 | Lack of intention to promote sustainable supply chain |
| | Lack of resources | LOR1 | Insufficient innovation ability of enterprises |
| | | LOR2 | Enterprises are underfunded |
| | | LOR3 | Lack of technical personnel |
| | | LOR4 | Backward management of the enterprises |
| | Market | MAR1 | Vicious competition among enterprises |
| | | MAR2 | The high cost of manufacturing |
| | | MAR3 | A low level of using new technologies in the whole industry |
| | Technology | TEC1 | Difficult to balance economic benefit, environmental benefit and social benefit |

(continued)

**Table 1** (continued)

| Constructs | Category | Code | Influence elements |
|---|---|---|---|
| | Government | GOV1 | Local policies have strict supervision over the use of new technology |

3.89), such as productivity, higher delivery rate and lower total cost which was also reported by Birasnav and Bienstock [21]. On the contrary, two government-related items (Policy support and Government's attention to production indicators and regulations) showed the lowest possible contributors (avg. score of 3.22 and 3.47 respectively). This result is inconsistent with Luken and Van Rompaey's [13] analysis of the driving forces behind the adoption of environmentally friendly technologies by several Chinese paper mills.

Concerning barriers, the most likely obstacle was found to be higher production costs (avg. score 3.68). The results of Luken and Van Rompaey's [13] study on obstacles show that the biggest obstacle is the implementation cost of new technologies, which is different from the high production cost proposed in this study. Lu et al. [29] showed that companies prefer low initial investment and high return technologies when studying the use of new construction technologies in Singapore. The second most important factor appeared to be the competition among industry enterprises (avg. score 3.65) which was followed by the lack of skilled personnel (avg. score 3.56). It is worth mentioning that the two most unlikely impediments are lack of awareness of using technology and lack of intention to promote sustainable supply chain, which corresponds to the second most crucial impediment factor (driven by the vision of the enterprise's development). It shows that SMEs in China have a strong sense of sustainable supply chain development and the use of new technologies.

Finally, the enablers and barriers were transformed into single dimension variables, as the Cronbach's Alpha value for enablers was 0.863 and for barriers, it was 0.852, which shows a high internal consistency. A correlation analysis was then carried out together with the economic, social and environmental performance measures. Table 2 shows the outcome of the correlation analysis. It is clearly evident that enablers and barriers are significantly correlated with the performance measures as coefficient were significant at $P < 0.05$ level. Since the overall enablers show a positive correlation with the three performance factors, hence verifying the first three hypotheses (H1, H2 and H3). The barriers also show a positive and significant correlation with the three performance factors, hence H4, H5 and H6 were not supported. Nonetheless, it should be noted that these barriers have a significant impact on these performance measures. The positive correlation between the barriers and performance measures could be due to the way these measures of the barriers were worded. The significant correlation itself indicates that SMEs need to overcome these barriers to take the advantage of new technologies to strengthen their position in the market. To further verify the findings of the correlation, a regression analysis was conducted which shows that altogether enablers and barriers explain around

**Table 2** Correlation analysis between the constructs

| | | Enablers | Barriers |
|---|---|---|---|
| Economic performance | Pearson | **.740**** | **.549**** |
| | Sig. (2-tailed) | .000 | .000 |
| | *N* | 100 | 100 |
| Social performance | Pearson | **.696**** | **.427**** |
| | Sig. (2-tailed) | .000 | .000 |
| | N | 100 | 100 |
| Environmental performance | Pearson | **.645**** | **.459**** |
| | Sig. (2-tailed) | .000 | .000 |
| | N | 100 | 100 |

**Significant at 0.05 level

63.3% of the variance (Adj. $R^2$ 0.633). Both coefficients from barriers and enablers were significant at the $P < 0.01$ level.

## 4 Conclusions

The main aim of the study was to identify a set of enablers and barriers to new technology implementation in manufacturing SMEs in the Pearl River Delta Region of China. Our study identifies government, market, society, internal motivation and advantages of technology as key enablers. The study also identifies a lack of awareness, lack of resources, market factors, government regulations and technological challenges as key barriers. The paper looked at the impact of these enablers and barriers on sustainable performance indicators (economic, social and environmental). The findings show that economic factors still occupy the primary position. Three more likely drivers of the use of new technologies for production activities are (1) market pressures from home and abroad; (2) the vision of the enterprise's development; (3) the apparent advantages of new technologies. On the contrary, the driving force from the government is insufficient, whether it is a relatively free market regulatory environment or tax-free welfare policies for small businesses, to promote the use of new technologies. The three major obstacles to the adoption of new technologies for production activities are: (1) higher production costs; (2) vicious competition among enterprises in the industry; (3) lack of technical personnel. The study showed that enablers and barriers both have a significant impact on the sustainable performance of SMEs. The perceptions of drivers and barriers are similar among the respondents with different enterprise sizes and job backgrounds, but there is no significant difference. This study will enable a deep understanding of the barriers and enablers of new technology implementation in SMEs in China. This study thus adds to the limited empirical research on SMEs in a developing context.

The research scope of this study however is limited to the Pearl River Delta region of China, and hence doesn't represent the same problems faced by SMEs in the whole country when using new technologies. Moreover, findings are based on just 100 survey responses. Future research can thus build on the limitations of the study focus on increasing sample size, adding more industry categories and perhaps collecting and comparing data from different developing regions. Additionally, using a mixed-methods approach will help in triangulation and generalization of findings.

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