

# How Big Data Drives Innovation? Evidence from China's Manufacturing Sector

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**Abstract:** The integration of Big Data and manufacturing has come to the research forefront in recent decade. In response to heightened economic uncertainty, Chinese manufacturers are stepping up efforts to increase production efficiency and flexibility, which are also in accordance with the standards of industry 4.0. This paper discusses how Big Data tools such as data mining, cloud computing and artificial intelligence are transforming China's manufacturing sector, which includes the optimization cases of supply chain management, lean & agile production, industrial internet platform. Meanwhile, this paper also conducts an empirical analysis by using the number of patent authorization with regards to Big Data technologies. It found that though Big Data innovations stem from the information technology sector, the mechanical engineering sector has been steadily catching up, while artificial intelligence and internet of things are the newly emerging fields. In the conclusion part, this paper answers important Big Data questions: (1) Will artificial intelligence replace human intelligence and lead to massive unemployment? (2) How can we better adapt to a Big Data-driven economy and make maximum use of the technological advancement? Moreover, it suggests that in the short run, Big Data application should be more user-friendly to reduce public resistance and win support; in the long run, Big Data knowledge should be instilled into every aspect of the education system to bring up generations with big-data mindset. Serving as a lighthouse, this paper opens the way to more systematic studies in the crossfield between Big Data and manufacturing.

## 1. Introduction

The technologies relating to Big Data are becoming increasingly important for real-world businesses nowadays, especially in fields such as software engineering, computer science and telecommunication. Big Data, also referred to as data science, incorporates the processes of massive data collection, data analyzing and data interpretation, which leads to the popular concepts of "Cloud Computing" and "Artificial Intelligence" [1,2]. Since "Industrial 4.0" was introduced in 2010s, the application of Big Data was further extended into the sector of manufacturing with the help of Internet of Things (IoT), which is intended for advancement in effectiveness and efficiency [3]. These progresses ranges from scrap rate reduction, uptime/downtime monitoring to marketing and supply chain management, allowing for reliability and flexibility. For example, Foxconn has reportedly replaced 60,000 factory workers with robots [4]. More and more industrial robots and CNC machines are now used to automate tasks and procedures that traditionally require human input, which is expected to reduce costs while improving speed and accuracy. In Shenzhen, Foxconn has successfully managed its "lights-off" factories with a 90% labor reduction, 30% productivity increase and 15% turnover time decrease (According to the announcement about "Lighthouses" by World Economic Forum (WEF) on 10th Jan, 2019).

This paper reviews the major Big Data applications in present manufacturing environments by focusing upon the specifics of varied industrial internet platforms (IIPs). These inventions were initially brought about by a coordinated digitization effort in the manufacturing sector, and were enlightened by the e-commerce boom. Connecting both external and internal customers, industrial internet renders transparency, efficiency and effectiveness to the conventional sourcing, production,

distribution and marketing practices of businesses. For empirical verification, we also resort to visualized analysis of Big Data-related patent data collected from Chinese manufacturing sector, with the aim to illuminate the trend of Big Data-related innovation and its fusion with manufacturing

The rest of this manuscript is organized as follows: section 2 investigates the impact of Big Data upon supply chain and lean & agile production management; section 3 illustrates the trend of Big Data innovation in China's manufacturing sector; section 4 concludes the whole article and provide suggestions for future Big Data development in manufacturing.

## **2. Literature Review**

### **2.1 Big data enhances supply chain efficiency**

There seems an increasing popularity in Big Data application by manufacturers to “linearize” their supply chain operations, which uses data mining, cloud computing and artificial intelligence as leverage to ensure high-performance procurement, warehouse, transportation and customer service [5]. These measures take the form of industrial internet and are conducive to a closer bond of affiliation between businesses. Characterized by speed, transparency and convenience, industrial e-commerce provides an utterly new channel for starting materials, intermediate, bulk and finished products, while transforming the once opaque marketplace with an abundance of data. Take MRO (Short for Maintenance, Repair and Operation) for example, although it seems like chores, yet imposes a nontrivial influence upon the bottom line. Still, a considerable number of entrepreneurs ignore MRO's potential and have to endure the extra costs of under-performing equipment capacity and even unpredicted breakdowns. According to China Renaissance, China's MRO market is estimated to total 1.2 trillion RMB by 2019 and still on rise, assuming MRO spending consists 4%-7% of China's total industrial output value. Conventionally, MRO was characterized as scale diseconomy with poor traceability, unconformable quality and unwarrantable after-sales service, which calls for a unified B2B platform: for customer, it ensures an abundance of supplies with reasonable pricing, reliable quality and rapid responsiveness; for vendor, it enables long-tail effect (E-commerce makes it possible to sell a wide range of products by appealing to many niche market where potential customers are physically dispersed in location), brings in timely feedback and allows for accurate forecasting. Meanwhile, B2B platform has proved to be Big Data driven when matching demand with supply. The digitization of processes generate a massive amount of trade-related data, which can be used for a variety of analytical needs such as: (1) provide an intelligent recommendation system by clustering customers based on their buying patterns; (2) present a variety of products with detailed specification thus to reduce purchasing costs and complexity; (3) display credibility and authenticity of both the buyer and the seller to minimize transaction risk; (4) bring about lead time reduction and stabilization by enabling real-time tracking; (5) accommodate a diversity of third parties' interface.

### **2.2 Big data facilitates lean & agile manufacturing**

The lean manufacturing is originated to Toyota in 1950s, and has appealed to countless businesses mostly manufacturers [6]. This new concept, though famed for its efficiency and control, can incur considerable saving and quality improvement. Agile manufacturing, on the other hand, coincides with that of “Industry 4.0” and places more emphasis upon adaptability, flexibility and responsiveness. The fusion between manufacturing and Big Data starts from the Industrial Internet of Things (IoT), which use sensors to probe the machines for weaknesses and predict possible breakdown of equipment [7]. These practices are becoming increasingly mainstream when more CNC machines and robots are in place, which contribute significantly to better productivity and bottom-line improvement. In other words, Big Data makes the “Intelligent Factory” possible.

Specifically, Big Data engages in the first-line production activities with a main focus on causes of equipment downtime and breakdown events. The algorithms developed in this regard give out predictions about possible obsolescence risks and bring up awareness beforehand, which in turn

makes the daily maintenance quick and easy. Moreover, industrial data analysis can also be conducive to achieve greater compatibility among equipment and systems [8]. In short, Big Data assists managers to open the “black box” of production by examining the parameters at the workplace and gives advice about favorable work conditions, required work procedures and preliminary interventions when necessary, which is essentially what “Intelligent Factory” means [9].

In addition, Big Data can also help shape an organization’s structure by facilitating outsourcing decisions. Since Cloud Computing allows global users access over the internet to a shared pool of resources, a closer collaborative bond among business partners are then formed within the industry: (1) Big Data makes industrial programming activities (CNC, robot, PLC etc.) outsourceable, i.e. codes are provided by third-party service provider, which allegedly alleviates the shortage of skilled workers in these frontier fields—Big Data is promoting the servitization of manufacturing and driving many enterprises to specialize in providing machining solutions instead of machines. (2) Cloud Computing makes spin-off possible of processes such as industrial design and product design by means of crowd-sourcing and open innovation—Cloud services are now bringing about Uber like technology start-ups who matches up production tasks in accordance with licensor’s request. (3) Big Data enables a dynamic interface with external logistic service provider while establishing a background environmental monitoring station like that of Alibaba.com—Big Data is building an all-inclusive partner ecosystem to coordinate a collaborative effort in delivery service. (4) Cloud Computing promotes the popularity of cloud storage and virtualization among businesses especially SMEs by cutting their IT spending nearly in half—Cloud service providers like AWS is helping businesses, including manufacturers, reduce the need for software engineers and developers, and minimize hardware investments such as servers.

### **3. Empirical Analysis**

#### **3.1 Time series: trends in industrial big data application**

We use China’s patent application data from CNKI database and focus our research upon three major industries, namely, chemical engineering, mechanical engineering and information technology. Filtering with the theme word of “Big Data”, we construct a patent sample of 14,858 pieces, among which 97.9% are those from the above-mentioned three major industries. Specifically, chemical engineering makes up 3.7% of the total, while mechanical engineering 23.8% and information technology 70.5%. As shown by Figure 1, China’s industrial Big Data application has emerged since the early 2010s; from 2013-2019, chemical engineering maintained an average growth rate of 66.8% annually in terms of Big Data-related patent, while mechanical engineering grew at 130.7% and information technology 55.1% (The average annual growth rate is obtained by geometric mean calculation). Although both chemical engineering and information technology have witnessed a declining growth rate, yet the growth rate of manufacturing engineering has experienced a U-shape pattern with a turning point low at 76.9% in 2017. Within Big Data, China’s manufacturing engineering is continuously catching up with information technology with regard to the share of intellectual properties, i.e. a number ratio of the two dropped to 7:5 in 2019 from 12:1 in 2013.

So, what’s behind the scene? Firstly, Big Data stems from the information technology and extends to new areas such as mechanical engineering and chemical engineering etc. Secondly, mechanical engineering is making an increasing proportion of industrial Big Data application, which can possibly be attributed to the integration of industrialization and informatization program launched by Chinese government in the recent decade. Thirdly, the re-acceleration in mechanical engineering happens to coincide with the issuance of the White paper, namely, “Industrial Big Data White Paper” by Chinese government, which illuminates the alternatives available to manufacturers for interfacing with Big Data. Lastly, the deepening fusion between mechanical engineering and information technology is likely to bring about more opportunities to new methods such as internet of things, industrial automation and cloud services.

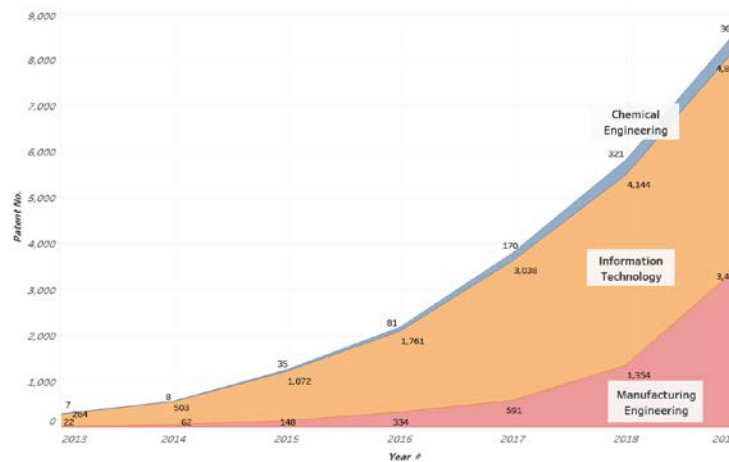


Figure 1 China Big Data-related Patent Application by Industry (2013-2019)

### 3.2 Pooling: fields of industrial big data innovation

We pooled the patent data over time and sort them out by sub-genres, and came up with the mathematical summation as shown by the Figure 2. The colored circles represent the numbers of patent application within each subfields, —i.e. the larger the circle is, the more number of designated patent applications. Thus, the relative size of circles can also imply the difference between maturity and emergence of innovation clusters. For example, computer equipment and data storage devices make up the largest two clusters (24.5%, 20.1% to total, respectively), while artificial intelligence and internet of things are among the smallest bodies (2.0%, 3.4% to total, respectively). This is not because that the former two clusters of innovations are proportionately important, but the latter two are newcomers. The rests are mainly about data processing (15.4% to total), algorithm (10.7% to total), cloud computing (8.6% to total), user interface (9.3% to total) and data collection (5.8% to total).

Big Data innovations can be subdivided into two classes, one is hardware oriented which mainly focuses on computer equipment and data storage devices (44.7% to total), the other is software oriented which consists of the rest in relation to data processing (55.3% to total) such as user interface, algorithm and artificial intelligence etc. The outnumbering of hardware innovation by software innovation reflects a shift of research emphasis, which is majorly concerned with processes of data collecting, data analyzing and data interpreting. Considering the daunting complexity of Big Data, the importance of user interface design has aroused more awareness among people. Moreover, the internet of things along with artificial intelligence will be the future growth engines for Big Data innovation.

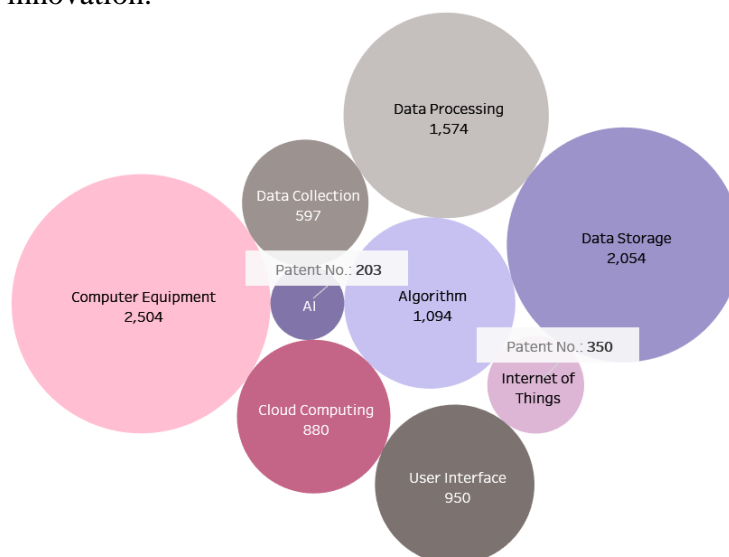


Figure 2 China Big Data-related patent application by subareas

#### 4. Conclusion

Since Big Data is rapidly transforming our modern life and business, two relevant questions are frequently asked: (1) will artificial intelligence replace human intelligence and lead to massive unemployment? (2) How can we better adapt to a Big Data-driven economy and make maximum use of the technological advancement? We hereby make the following conclusion:

In the short term, Big Data, especially artificial intelligence, will be inducing a structural change in the pattern of labor demand, where labor shortage mainly comes from the computer engineering sector. In fact, more people are needed to manage the robot instead of the job itself and unskilled labor are then referring to those who cannot program. Therefore, it becomes an urgency to lower the entrance barriers for Big Data application by introducing more user friendly interface and allowing for greater automation. Technologies that can be learned intuitively have proved to be less resisted and more productive at the workplace.

In the long term, the values and practices of Big Data need to be instilled into our education system, for purpose of ensuring satisfaction of a broad customer base. It is essential to customize Big Data studies by research / application focus to improve learning effectiveness of different demographics such as “professionals vs amateurs”. Meanwhile, the knowledge of Big Data should be imparted to students at an even early age, with the aim to fuse Big Data intelligence with intuitive thinking. And it would be better for universities to incorporate in every means Big Data methodologies into full scale scientific disciplines, thus to broaden minds, inspire innovations and empower practitioners. In short, fostering a Big Data-friendly culture will undoubtedly allow us greater access to the incoming technological revolution, which could bring in more opportunities than threats.

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