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*Research Article*

# How 3D Printing Subverts Global Production Networks after COVID-19: Evidence from a Labor-Intensive Industry

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*Purpose*. COVID-19 has prompted more countries to consider moving key production activities back home. 3D printing (3DP) is a key technology to realize this migration. This study aims to explore the extent to which 3DP can change the current global production network. *Design/Methodology/Approach*. This study takes the toy industry as the empirical object and studies the trend of labor-intensive industries migrating from China to the United States from the micro- and macroperspectives. At the microlevel, this study uses scenario analysis to compare the utility experience of different toy acquisition channels for consumers. At the macrolevel, this study determines the applicable product objects of 3DP through the classification and analysis of toy trade data. *Findings*. It is found that, with the development of 3DP, toy manufacturing activities may gradually flow from China to the United States in stages. If 3DP is implemented in electronic materials and power systems, this migration activity will be more obvious. *Originality/Value*. This study identified which kind of 3DP technology development will significantly promote the global production network reconstruction. This viewpoint is helpful for decision-makers to consider technology investment comprehensively.

## 1. Introduction

*1.1. Key Role of 3DP in the Pandemic.* Since the end of 2019, the coronavirus disease (COVID-19) epidemic has ravaged the world, and people's lives have been seriously affected. To stop the global spread of the epidemic, many countries have implemented severe blockade measures. The global supply chain is limited or even broken, which leads to a shortage of specific materials. When the capacity of overseas production hubs cannot meet the needs of emergency supplies, the important role of 3DP begins to appear [1]. According to Thingiverse, which is the largest open-source 3DP community in the world, taking medical supplies as an example, open-source designs such as 3D printed ventilator core spare parts and personal protective equipment have appeared in succession during this period. In addition to makers' open-source solutions, manufacturers have also opened up 3DP licenses for specific parts. All these contribute to the world's fight against COVID-19 [2].

COVID-19 has seriously affected the world economy and intensified the spread of deglobalization. This dilemma is prompting people to examine whether the global production networks (GPNs) should make appropriate changes. Not only medical supplies but also other industrial chains may migrate back to the developed countries [3]. Since 3DP can greatly reduce the entry threshold of the manufacturing industry and even realize the self-manufacturing of the family environment in specific scenarios, it has been paid attention and praised by policymakers continuously.

*1.2. 3DP and GPNs.* The cross-regional layout of the design, production, marketing, and other business activities under the leadership of multinational corporations has shaped GPNs. However, 3DP is an innovative technology that can subvert the current GPNs [4] and can directly transform a digital file into a physical product through a universal manufacturing machine [5]. While consumers can meet their daily material demands through one or two 3D printers, this manufacturing process of the future will proximate the location of the consumer [6]. When everyone can print the desired products from their own location, the existing GPNs will be severely affected [7, 8]. Is this the end of globalization and the beginning of deglobalization?

Currently, there are more than 100 kinds of materials, such as thermoplastics, metals, nylon, acrylic, gypsum, ceramics, and edible materials that could be used for 3DP [9–17]. Nevertheless, 3DP has been studied for approximately 30 years, and the development of the technology is not as universal as expected. Reasons include expensive equipment and filaments required for printing, poor printing quality of the desktop machines, and slow printing speed [18]. The community understands that "can be printed" does not mean "should be printed." When consumers choose the way to obtain products, they ask "what can be produced with 3DP?" and "what can uniquely be done using 3DP technology?" This pandemic may provide an appropriate answer to the applicability of 3DP. However, whether GPNs will be subverted to a greater extent needs to be proved by more cases.

## 2. Research Idea

*2.1. Theoretical Basis.* To examine how 3DP can subvert the current GPNs, we used disruptive innovation theory to analyze the issue [19, 20]. Disruptive innovation has four characteristics: noncompetitive, at the low-end of the introduction stage, simple, and customer value-oriented. When a new technology runs with those characteristics, it can be accepted by the public as a significant industrial mode. However, the current 3DP has not fully met these four characteristics. How can 3DP reach its full potential? Can 3DP coexist with globalization or will it precipitate deglobalization? In this study, we investigated toy manufacturing, which is a labor-intensive industry. Compared with the capital-intensive industry and technology-intensive industry, the labor-intensive industry is low-end. The international migration of labor-intensive industries is also the main feature of GPNs. Thus, we analyzed the impact of 3DP on the toy industry based on the four characteristics of disruptive innovation and evaluated the evolution of the GPNs trend.

Toy manufacturing is an ideal entrance for 3DP into a low-end market. The primary material of most toys is plastic. A 3D printer can use fused deposition molding (FDM) or stereolithography apparatus (SLA) technology to print the toy's main body directly, so its cost is relatively low when compared to metal component printing. Additionally, its life cycle requirement is not high, since it focuses more on the novelty and personalization of the toy. 3DP can stimulate toy users' enthusiasm to realize innovation. According to Petersen et al., if consumers downloaded 3DP designs online and printed toys at home, it could save 40% to 90% of the toy's purchase cost [21]. Consumers' interactions in the online community could also inspire creativity and result in the invention of some novel toys and games. This open-source distributed manufacturing paradigm could bring consumers higher value items for less money [22].

*2.2. Research Method.* The impact of 3DP in the supply chain is a frontier; however, historical and global statistical data are lacking. Research has focused on case studies, such as a study by Liu et al. [11]. Certain data lacking in these case studies were supplemented by experimentation, such as research conducted by Wittbrodt et al. [22], or scenario modeling, that is, work by Petersen et al. [21]. This research is to analyze the impact of 3DP on globalization and the data source should not be limited to only one country but should include leading import and export countries. At present, China is the world's largest producer and exporter of toys and the USA is the largest importer of toys made in China. Given our focus on globalization, we investigated toys made in China and exported to the USA and determine the differences between the toy supply chain before and after 3DP application.

Based on micro- and macrodata from the toy industry in the USA and China, this research discusses the impact of 3DP on globalization. In the current study, at the microlevel, a case study within scenario modeling is carried out, focusing on the process of American consumers obtaining My Little Pony toys through different channels. At the macrolevel, Chinese export data are analyzed to determine which categories of the toy are suitable for 3DP.

## 3. Data Analysis

*3.1. Microlevel.* 3DP has been used to create simple toys. For example, Hasbro and Shapeways cooperated to produce personalized My Little Pony toys in the United States. Will the manufacturing activities of these toys reflow the consuming countries? What benefits will the relevant participants receive? Rehnberg and Ponte hypothesized that 3DP for end-users would enhance consumer participation and bring more profit to the manufacturing side, making the low-middle "smile curve" become a flatter "smirking curve." Profit was the main driving force of the manufacturing return from developing countries to developed countries [23]. We study a typical case of My Little Pony toy coproduced by Hasbro and Shapeways. Hasbro is a famous multinational company, and Shapeways is a professional 3DP online platform in the USA. The manufacturing process differs from conventional injection molding.

In this section, we create an application scenario based on actual data and investigate this scenario. When a US consumer wants to obtain a plastic My Little Pony toy, he can acquire the toy through three distribution channels. We compare the cost, rate, and quality of these channels to determine the influence of 3DP on plastic toy manufacturing. The first channel is a US consumer making the toy herself (Figure 1). The second channel is a US consumer ordering a custom toy from an online platform (Figure 2). The third channel is a US consumer buying a toy from a shopping website, while a Chinese factory makes the toy through injection molding (Figure 3). In each

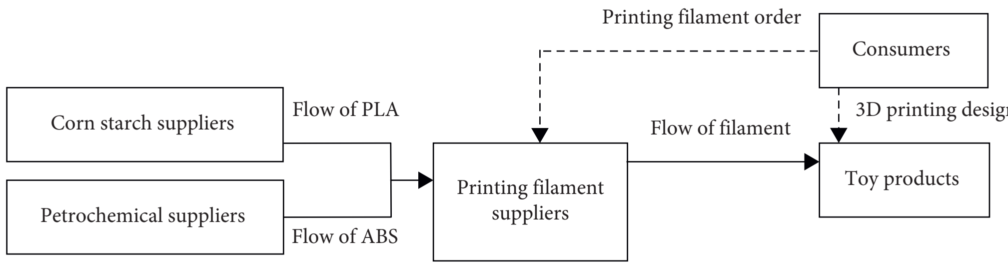


Figure 1: US consumers buy printing filaments to print toys themselves. Data source: authors.

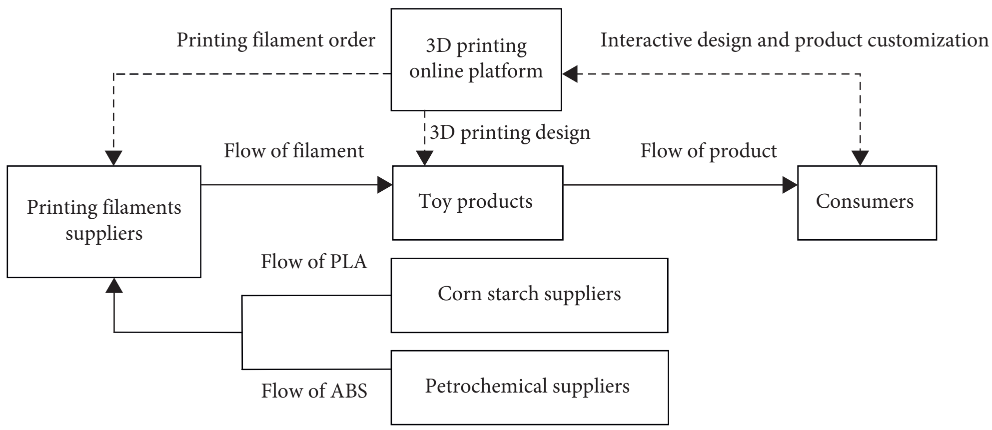


Figure 2: US consumers trust an online platform to print personalized toys. Data source: authors.

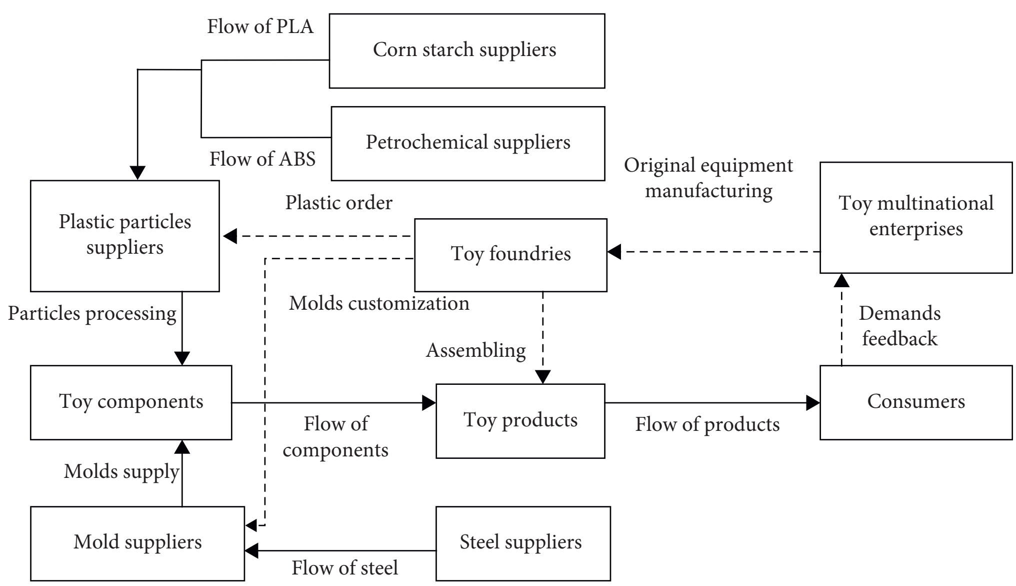


Figure 3: Chinese foundries mass manufacture toys through injection molding. Data source: authors.

figure, the solid line indicates the physical flows, and the dotted line indicates the nonphysical flows. The physical flows include raw materials, molds, and finished-products. Among these, the raw materials include two common plastics, acrylonitrile butadiene styrene (ABS) or polylactic acid (PLA). ABS is a petrochemical and PLA is a bioplastic. The molds are made of steel. The nonphysical flows include information exchange among consumers, channels, and suppliers.

The scenario data were from 3 leading enterprises; the 3DP platform data were from Shapeways (https://www.shapeways.com); the US retailer data came from Amazon (https://www.amazon.com); and the Chinese wholesaler's data came from Alibaba (https://www.alibaba.com). We selected My Little Pony toys with the same specifications from these websites. Ten different suppliers from Amazon and Alibaba were sampled; we took the average of these data to make the data more representative. The logistics costs were calculated based on the open market quotation. We treated the data from the scale manufacturing using a per batch average. We set the toy's measurement as $5 \times 5 \times 5\,\text{cm}^3$ and its weight as 50 g. Table 1 indicates the parameters of the different channels.

Table 1 shows that, in the process of toy acquisition, the 3 channels have varying characteristics. The desktop printer can immediately create the required products as long as there are filaments available [24]. Consumers can make as much as they want, without restriction subject to patent and copyright constraints [25]. However, for ordinary users, the challenges lie in the unprofessional digital file design and poor printing quality [26]. Although open-source machines are inexpensive, it is difficult for users to get started. If they do not have the skills to construct the digital model, the modeling software is insufficient, or the postprocessing is lacking (such as polishing and coloring), the use of such self-made toys will result in a poor experience for the ordinary consumer, especially children [27]. Thus, 3DP is more suitable for creative makers with professional knowledge and a pioneering spirit.

A customized toy from a professional platform is more suited to consumer demand [28, 29]. Furthermore, its quality will be higher. Consumers can fully participate in the personalized design of products using the suggestions of skilled designers [30, 31]. By obtaining a toy from the platform, the total price includes material cost, machine depreciation, labor service, logistics, and platform profit. The consumer of the customized toy pays less than that of the self-made one because he has saved the initial acquisition fee of the printer. Compared to the conventional model, a 3DP customized toy shortens the length of the whole supply chain. Moreover, it has a quicker and more flexible response to consumer demand.

The advantage of the conventional mode is its low cost and high profit. The low cost comes from the material, labor, large-scale production, and efficient global logistics. Even considering tariffs, the big difference between the wholesale and retail price still ensures retailers a profit margin. Therefore, they are able and willing to maintain the proper safety of their inventory. Retailers also want to optimize the lead time to ensure the supply of goods. For consumers, if they acquire the toy from a conventional channel, either by courier or on-spot shopping, they will receive it quicker than from the 3DP platform.

3DP can shorten the length of the supply chain [32]. However, from the consumer's point of view, it takes more time than conventional channels. Buying a My Little Pony toy from Shapeways or Amazon takes almost the same transportation time in the USA (about 3 days by courier). However, the consumers using the platform need to wait an additional 5 days for the production by Shapeways. If a consumer orders it from Amazon, the toy can be delivered in 2 days. The consumers using the platform spend almost 8 times the price of the conventional toy but do not receive it quicker. Figure 4 shows the time spent on the three channels.

Based on the above analysis, we rated the three channels according to product price, product quality, consumer waiting time, and personal satisfaction. $Pi$ represents product price, $Qi$ represents product quality, $Ti$ represents consumer waiting time, and $Si$ represents personalized satisfaction. The scoring standards are as follows. For some subjective variables, such as $Qi$ and $Si$, the scoring criteria refer to the Wohlers report, which is the authoritative report of the 3DP industry [33].

For $Pi$, the cheapest is set to 3, the medium cost to 2, and the most expensive to 1. Its weight is set to $a$.

For $Qi$, the best is set to 3, the medium quality to 2, and the worst to 1. Its weight is set to $b$.

For $Ti$, the shortest is set to 3, the medium amount to 2, and the longest to 1. Its weight is set to $c$.

For $Si$, the best is set to 3, the medium to 2, and the worst to 1. Its weight is set to $d$.

Therefore, we set the comprehensive consumption experience of channel $i$ as $Ei$. Its calculation is set in the following equation:

$$Ei = aPi + bQi + cTi + dSi. \tag{1}$$

Table 2 shows the score results.

According to Table 2, $E1$ equals $a + b + 3c + 2d$, $E2$ equals $2a + 3b + c + 3d$, and $E3$ equals $3a + 3b + 2c + d$. Different consumers attach importance to different indexes. Therefore, under different preferences, the weights of $a$, $b$, $c$, and d have their values as follows.

When consumers have no unique preferences, $a = b = c = d$. Thus, $E2 = E3 > E1$. Channel 2 and Channel 3 bring consumers nearly the same comprehensive experience. This score demonstrates that the competitiveness of the conventional model is not less than that of 3DP.

When consumers are more sensitive to product price, weight $a$ is higher. At this time, $E3 > E2 > E1$. This type of consumer pays more attention to the price advantage of Channel 3, and their interest in 3DP toys is not as significant as expected [34].

When consumers are more sensitive to product quality, weight $b$ is higher. At this time, $E3 > E2 > E1$. This type of consumer is similar to the first category, still first choosing to buy toys through Channel 3, and then trying Channel 2 or Channel 1.

When consumers are more sensitive to consumer waiting time, weight $c$ is higher. At this time, $E1 > E3 > E2$. The first choice is to print toys at home, which is a good choice for this type of consumer. However, the suboptimal choice is Channel 3 instead of Channel 2 from Figure 4.

When consumers are more sensitive to personalized satisfaction, weight $d$ is higher. At this time, $E2 > E1 > E3$. The platform can provide more professional, customized services, which is undoubtedly the preferred channel. Although the quality of consumer-made toys is a little worse, it is also the second-best choice and more self-sufficient than Channel 3.

Each of the three channels has its advantages. There was initially much hype about the concept of 3DP after the article "A Third Industrial Revolution" was published, and desktop

Table 1: Comparison of the three channels. Data source: Shapeways (https://www.shapeways.com), Amazon (https://www.amazon.com), and Alibaba (https://www.alibaba.com).

| Channel description | Single acquisition cost (US dollars) | Material cost (US dollars) | Initial machine cost (US dollars) | Quality | Delivery cost (US dollars) | Delivery time (days) | Production time (days) |
|---|---|---|---|---|---|---|---|
| Consumer (self-made) | Material cost + machine cost depreciation | 2.55–3.75, (PLA/ABS filament) | 700–1000, (desktop FDM printer) | Low | 0 | 0 | 0.5–1 |
| Customization from the platform | 60 | 2.55–3.75, (PLA/ABS filament) | 3000–7000, (industrial FDM printer and auxiliary equipment) | High | 6 (by courier in the USA) | 3 (by courier in the USA) | 5 |
| Buying from a shopping website | 8 (retail in the USA) 2 (wholesale from China, excluding freight cost and tariffs) | 0.15, (PLA/ABS particle) | 5000–15000, (injection molding machine and auxiliary equipment) | High | 6 (by courier in the USA) + 0.5 (shipping from China's foundry to the USA) | 3 (by courier in the USA) + 20 (shipping from China's foundry to the USA) | 25 |

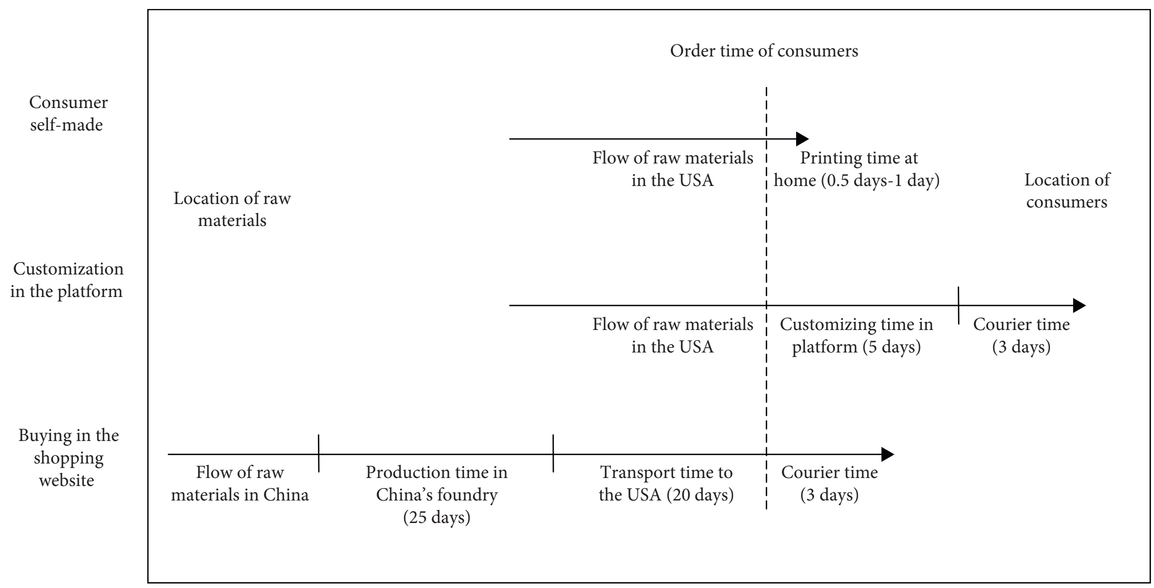


Figure 4: Comparison of the lengths of the supply chains of the three channels. Data source: authors.

Table 2: Comparison of the comprehensive consumption experience of the 3 channels. Data source: authors.

| Number | Channel description | *Pi* | *Qi* | *Ti* | *Si* | *Ei* |
|---|---|---|---|---|---|---|
| 1 | Consumer (self-made) | 1 | 1 | 3 | 2 | $a+b+3c+2d$ |
| 2 | Customization from the platform | 2 | 3 | 1 | 3 | $2a+3b+c+3d$ |
| 3 | Buying from a shopping website | 3 | 3 | 2 | 1 | $3a+3b+2c+d$ |

printers became popular [3]. However, soon users of those printers realized that they did not really know what to print. When the market returned to rationality, after 2018, there was a significant increase in sales of industrial-grade 3DP systems. However, sales of desktop-grade printers below $5,000 grew slowly [33]. Since the users of Channel 2 use more industrial-grade equipment, while the users of Channel 1 choose desktop-grade devices more often, we can infer that Channel 2 is more popular with users than Channel 1. Therefore, at the microlevel, we conclude that most consumers will access the toy products via Channel 3, then Channel 2, and finally Channel 1.

*3.2. Macrolevel.* With the maturity of various 3DP technologies, some of the current thresholds are likely to be overcome, such as cheaper equipment and filament emerging, more refined printing quality, and faster printing

Table 3: 3DP feasibility score for routine manufacturing of different products. Data source: Wohlers reports [34, 39–42], Petersen et al. [21], and Laplume et al. [43].

| $3D_j$ score | Routine manufacturing feasibility | Description |
|---|---|---|
| 1 | It is difficult to realize routine 3DP manufacturing in the near future. | The core components of the product are electronic components and chips, or other components that are difficult to make by 3DP, such as wires or small complex power devices. |
| 2 | It can be realized in a professional workshop environment. | The product is more suitable to make in a workshop environment due to the technical limitations of 3DP, such as the requirements of the materials, speed, quality, and size. Nearly all the metal printing activities belong to workshop manufacturing. |
| 3 | It can be realized at home, but some extraprocessing is needed. | The product may be made of a single nonmetallic material, and the size and printing speed requirements are not high, so it is suitable for home printing. However, the product structure is complex. The home printing staff needs to learn more professional knowledge for extraprocessing. |
| 4 | It can be easily realized in the household environment. | The product is suitable for home printing and meets the instant personalized needs of the user; its other requirements are relatively low. |

speed [35–37]. If the mode of My Little Pony toys can be replicated in other categories, more US consumers will print their favorites at home or through the online platform. Then, that will change the trade between the 2 countries and affect the global manufacturing activities of this industry [38].

We divided the toys into 4 classes according to their 3DP routine manufacturing feasibility, which is shown in Table 3. We used the Wohlers Report, Laplume et al., Petersen et al., and a field investigation of Chinese toy manufacturers [21, 39–43] to score the 3DP manufacturing feasibility of the toy type *j*, which is called 3*Dj*. We assigned other toys that were difficult to categorize a score of 2 (average).

The type of international trade is related to the probability of manufacturing migration after 3DP mass application. In terms of international trade, we divided the trade into two types, general trade and nongeneral trade. General trade means that the product is designed and manufactured by local producers and then exported with its own brand. Nongeneral trade, which is mainly processing trade, means manufacturing and exporting after receiving foreign orders. The design, material, or brand will follow the instructions of the foreign buyers. Globalization has promoted the development of the processing trade and increased the discourse power of overseas buyers in the toy supply chain. Contract manufacturing and original equipment manufacturer (OEM) models belong to the nongeneral trade.

In the toy export volume from China to the USA, the average proportion of nongeneral trade has reached 59.43% according to the 2019 data. If Chinese manufacturers do not improve their technical competitiveness, they are likely to be replaced in the future. When 3DP is popular, overseas buyers may choose to print toys directly in their own countries. Thus far, Chinese manufacturers have not carried out many 3DP activities to produce final products [34].

Based on the above consideration, we analyzed the toy export data in different types of trade from China to the USA. If a type of toy can be easily produced by 3DP and its current export type is dominated by nongeneral trade, the Chinese foundry has no initiative in the toy processing business, as its manufacturing activity is more likely to migrate from China to the USA.

We set the nongeneral trade proportion of the toy type *j* as *Pj* and set the manufacturing activity migration score as *Aj*. The relationship among *Aj*, 3*Dj*, and *Pj* was set in the following equation:

$$Aj = 3Dj\,^{*}Pj. \tag{2}$$

All the scores for *Aj*, which are based on the toy data of the exports from China to the USA, are shown in Table 4.

The higher the value of 3*Dj*, the easier it is for 3DP routine manufacturing to be realized. The US families and workshops can manufacture these toys by 3DP domestically. The higher the value of *Pj*, the higher the proportion of the processing trade. It is easier for US multinationals to relocate the processing site of this type. For a specific type of toy, if *Aj* is higher, the relevant multinationals are more likely to transfer their toy manufacturing activities from China to the USA, for example, My Little Pony. The grading and classification of Chinese toy export refer to Chen's research to analyze the influence of 3DP on toy manufacturing migration. According to Chen's research, if the products had similar scores for *Aj*, their probability of manufacturing activity migration was also similar [44]. Therefore, different types of toys were sorted from high to low according to the value of *Aj* and divided into three grades. The score of the first grade is over 2, the second is between 1 and 2, and the third is below 1. Table 5 shows the results.

For the toys of the first grade, which only includes dolls and accounts for 2.90% of all toys, the technical content is not high. They are easy to print with a desktop printer. If multinationals want to improve the toy production mode by 3DP, this toy type is a good choice to start. The toys of the second-grade account for 31.30% of the total exports. Intelligent toys are easy to make using desktop 3D printers. Wheeled toys, such as baby carts, are designed and sold mainly by US companies, although they are specially manufactured in 3DP workshops, not households. If the manufacturing activities of the second-grade toys migrate back to the US, they will have enough orders for workshops to start up suitable machines to mortise of their initial costs. If 3DP technology continues to mature, the toys of this grade

Table 4: Manufacturing activity migration score based on toy exports from China to the USA, 2019. (data source: China customs statistics).

| Category | Nongeneral trade export (US dollars) | Total exports (US dollars) | Proportion of nongeneral trade $P_j$ (%) | 3DP manufacturing feasibility $3D_j$ | Manufacturing migration score $A_j$ |
|---|---|---|---|---|---|
| Other toys | 1,965,323,993 | 3,694,686,171 | 53.19 | 2 | 1.06 |
| TV game machines and parts | 2,647,614,931 | 2,718,923,240 | 97.38 | 1 | 0.97 |
| Christmas products | 749,334,311 | 1,872,797,014 | 40.01 | 2 | 0.80 |
| Other video game machines and parts | 1,946,318,845 | 1,960,916,035 | 99.26 | 1 | 0.99 |
| Toys with power devices | 495,728,471 | 931,578,261 | 53.21 | 1 | 0.53 |
| Intelligent toys | 283,391,753 | 782,380,321 | 36.22 | 3 | 1.09 |
| Animal toys | 221,954,103 | 974,875,873 | 22.77 | 3 | 0.68 |
| Other festival or entertainment items | 132,140,590 | 915,421,446 | 14.43 | 2 | 0.29 |
| Tricycles, scooters, and other wheel toys | 75,250,258 | 413,013,429 | 18.22 | 2 | 0.36 |
| Dolls | 309,218,591 | 449,943,090 | 68.72 | 4 | 2.75 |
| Baby carts | 224,762,684 | 373,462,469 | 60.18 | 2 | 1.20 |
| Other game machines | 139,440,549 | 155,979,802 | 89.40 | 1 | 0.89 |
| Bicycles under 16 inches tall | 5,967,649 | 135,426,462 | 4.41 | 2 | 0.09 |
| Mountain bicycles | 10,030,199 | 106,793,867 | 9.39 | 2 | 0.19 |
| Music boxes and mechanical devices | 2,706,687 | 9,946,399 | 27.21 | 2 | 0.54 |
| Total | 9,209,183,614 | 15,496,143,879 | | | |

Table 5: Sorting and grading of the manufacturing activity migration score based on toy exports in 2019 (data source: authors).

| Category | Total exports (US dollars) | Proportion of this category to all toys (%) | $A_j$ | Grade | Proportion of this grade to all toys (%) |
|---|---|---|---|---|---|
| Dolls | 449,943,090 | 2.90 | 2.75 | 1 | 2.90 |
| Baby carts | 373,462,469 | 2.41 | 1.2 | | |
| Intelligent toys | 782,380,321 | 5.05 | 1.09 | 2 | 31.30 |
| Other toys | 3,694,686,171 | 23.84 | 1.06 | | |
| Other video game machines and parts | 1,960,916,035 | 12.65 | 0.99 | | |
| TV game machines and parts | 2,718,923,240 | 17.55 | 0.97 | | |
| Other game machines | 155,979,802 | 1.01 | 0.89 | | |
| Christmas products | 1,872,797,014 | 12.09 | 0.8 | | |
| Animal toys | 974,875,873 | 6.29 | 0.68 | | |
| Music boxes and mechanical devices | 9,946,399 | 0.06 | 0.54 | 3 | 65.80 |
| Toys with power devices | 931,578,261 | 6.01 | 0.53 | | |
| Tricycles, scooters, and other wheel toys | 413,013,429 | 2.67 | 0.36 | | |
| Other festival or entertainment items | 915,421,446 | 5.91 | 0.29 | | |
| Mountain bicycles | 106,793,867 | 0.69 | 0.19 | | |
| Bicycles under 16 inches tall | 135,426,462 | 0.87 | 0.09 | | |
| Total | 44,656,817,822 | 100 | | | 100.00 |

will follow the trend of the first grade and transfer more production sites back to the United States. However, first-grade and second-grade toys account for only 34.20% of the total exports; thus, the GPNs did not change dramatically.

For the toys of the third grade, which account for 65.80% of the total exports, there is a need for a higher demand for disruptive innovation. The most substantial proportion is game machines, toys with power devices, and festival items. The game machine category involves a variety of materials and contains precise circuit boards (PCB) and electronic components. At present, it is difficult to print these components directly [45, 46]. The category for toys with power devices was divided into two parts: shells and power devices. 3DP can customize the former, while the latter is composed of various materials and has a complex structure. The power device needs to be manufactured in other ways and embedded according to the shape of the shell. The festival item category has a simple structure. It mainly focuses on making deliveries before Christmas or other festivals with low prices. Its personalized requirements are not high, and it is more suitable for scale production. If a festival item is to be manufactured by 3DP, it needs to be produced quickly to meet the festival demand and significantly lower its unit cost; currently, the expensive filament cost and slow printing speed are shortcomings of 3DP.

## 4. Conclusion

*4.1. Main Findings.* COVID-19 has led more countries to consider moving some of their key production activities back home. However, will labor-intensive industries, which are most sensitive to production costs, migrate if 3DP is applied? Taking the toy industry as an empirical object, we examined the characteristics of disruptive innovation and carried out micro- and macroverification of our prediction. It is found that, with the development of 3DP, toy manufacturing activities may gradually flow from China to the USA, and the proportion of inflow at various stages is shown in Table 5. 3DP of electronic materials and power systems is the key to achieving a more dramatic change in toy manufacturing patterns. In addition to technical limitations, when promoting 3DP products, multinational companies also need to assess a range of factors, including the overall effect of production costs, logistics efficiency, and consumer demand.

*4.2. Future Research.* There are still many uncertain factors affecting 3DP in the toy industry. Future research should include the following objectives.

*4.2.1. Research Method Improvement.* In this paper, we focused on the toy trade between the USA and China and then measured the impact of 3DP on globalization. However, the relationship of the relevant variables was not fully quantified for two reasons:

(1) 3DP was not applied by the consumers, distribution channels, or the suppliers in the toy industry on a large scale. There are only a few application cases available. Thus, there is little relevant data for ordinary quantization methods.

(2) Data for homemade products is difficult to obtain accurately. What do consumers print at home? This data cannot be easily collected, which in contrast to sales data that can be obtained from manufacturers or retailers. Therefore, it is difficult to know the purposes of private users. The alternative relationship between 3D printed products and specific traditional products cannot be easily determined. In the future, more appropriate research methods and alternative variables should be developed to quantify the impact of 3DP.

*4.2.2. Political Intervention Research.* At present, the development of 3DP is dominated mainly by market forces. However, it is undeniable that some of these forces come from governments. Governments want to quickly occupy a future market through the development of new technology to obtain political capital. However, these political interventions may not always be positive. 3DP is a kind of automation technology. Automation is not able to significantly increase low-end jobs. Even if the manufacturing activities return to consuming countries, the employment rate may not improve as much as expected. Then, local politicians will reduce their enthusiasm for this technology and may cut industrial subsidies. As a result, the momentum of 3DP's development may slow down. Traditional processes may not be properly replaced by 3DP because some politicians want to maintain a certain employment rate. In the future, a more in-depth discussion should be carried out to observe whether political interventions are positive or negative for 3DP.

*4.2.3. Logistics Mode Evolution.* The current global production layout has led to the prosperity of the international logistics business based on transnational containers. This research shows that if 3DP electronic components and power systems are realized, more production activities will flow into the region around end consumers. Centralized production will be replaced by distributed production, followed by the decline of the international logistics hub and the rise of the local 3D printing platform. The former takes container as the main transportation object, while the latter takes 3D printing consumables as the main one. Future research should focus on how the logistics model should evolve to better adapt to the local flow of 3D printing consumables and consumers' demand for instant printing.

*4.2.4. New Category Emerging.* The results of this research were restricted by the existing toy classification standard. In the world where COVID-19 is popular, more people will be asked to work remotely at home. Will this create new demand? Will toys and other consumer goods have a new evolutionary trend? Will the industry develop a more attractive category using the characteristics of 3DP, rather than the alternatives of conventional categories? For example, mobile games use virtual reality and augmented reality technologies. These games may replace conventional TV and PC games. Similarly, will the definition and globalization of the toy and other labor-intensive industries undergo a great unexpected change?

Further research in this field is not only based on the development of technology but also linked with political and economic factors. Academic researchers should focus on typical application cases in the industry to understand the relevant development trends and carry out interdisciplinary discussions.

## Data Availability

The data used to support the findings of this study are included within the article.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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