IMPACTS OF ADDITIVE MANUFACTURING ON GLOBAL VALUE CHAIN AND RESHORING

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Abstract(EN):

Industrial revolution coupled with technology advancements has been showing it's impacts not only on Economies but also on the way business done, especially on Multi-National Companies.

So far, we have seen three Industrial Revolutions and now the era of evolution of fourth Industrial revolution which comprises of several technologies including 3D Printing, Artificial Intelligence and so on.

In this thesis we focused our concentration on 3D Printing which is also called Additive Manufacturing and analysed its potential Impacts on International Business.

Abstract(IT):

La rivoluzione Industriale, accompagnata dal progresso tecnologico, sta mostrando le sue conseguenze non solo nel campo dell'economia ma anche nella realtà aziendale, in particolare nel modo di operare delle multinazionali.

Fino ad oggi abbiamo osservato tre Rivoluzioni Industriali, ed ora stiamo vivendo nell'era dell'evoluzione della quarta rivoluzione Industriale, caratterizzata da numerose tecnologie quali la stampa 3D e l'Intelligenza Artificiale.

In questa tesi abbiamo concentrato la nostra attenzione sulla stampa 3D, conosciuta anche con il nome di Produzione Additiva, e analizzato le sue conseguenze nel Business Internazionale.

Acknowledgement:

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LIST OF ABBREVIATIONS

3D Printing	-	Three-Dimensional Printing.
GVC	-	Global Value Chain.
ICT	-	Information and Communication Technology.
AM	-	Additive Manufacturing.
LEAP	-	Leading Edge Aviation Propulsion.
IP	-	Intellectual Property.
IB	-	International Business.
R&D	-	Research and Development.
GE	-	General Electric.
BCG	-	Boston Consulting Group.
UA	-	Under Armour.
UNCTAD	-	United Nations Conference on Trade and Development.
UPS	-	United Parcel Services.
CAD	-	Computer Aided Design.
UAW	-	United Automobile, Aerospace, and Agricultural Implement workers of America

Table of Contents

Figures, graphs, and Tables.

1. Introduction

Since ages textile industry was relied on hand weaving done by individuals at their homes. Then, in the late 18th century, it was mechanised which lead to First Industrial Revolution that brought hundreds of individual weavers together and the factory was born. Later the invention of steam engine, fuel engines and jet engines connected the world and Henry ford brought new production techniques in production lines changed the way manufacturing done that results to increase in efficiency and output, which has been regarded as Second Industrial Revolution. Advancements and Innovation in ICT connected the world digitally and manufacturing was digitalized, that's considered as Third Industrial Revolution.

Now, in this digital era, some advancements in the new and old technologies has been changing the way of manufacturing and processes. These technologies include 3D printing also called Additive Manufacturing, Robotics, Artificial Intelligence etc. Especially when we think about Additive Manufacturing, even though it is not a new technology as it available since 1980's which was mainly used at R&D level. As the years pass by, the technology is now coming into main stream production level.

In this thesis work, we have analysed how additive manufacturing is impacting International Business arena focusing on the hypothesis that this technology could affect the way of doing business and could have an impact on developed and developing countries.

The following section 2 discusses a brief introduction about Additive Manufacturing and available Technologies and the possible benefits and drawbacks that Additive Manufacturing could offer and discussion on the industries that 3D Printing could impact most. In the section 3, I discussed how 3D Printing changes the Global Value Chain by focusing on Off-shoring and Re-shoring phenomena and discussed on the research question, Reshoring due to Additive Manufacturing. The section 4, provides the empirical evidence for the research question by analysing three case studies.

2. ADDITIVE MANUFACTURING

2.1. Literature Review

The purpose of literature review is to give an overview about the 3d printing technology and its implications on international Business arena by analysing the advantages and dis-advantages proposed by different authors and then it focuses on drawing up and discussing some main areas where it has been showing its effects or will show soon. Till now as there is no convergence among the authors on the impacts of Additive manufacturing on doing Business, I proceeded the literature review by drawing out the main thoughts and views of authors and tried to put similar views together.

2.1.1. What is Additive Manufacturing

3D printing, also known as additive manufacturing (AM), refers to processes used to create a three-dimensional object in which layers of material are formed under computer control to create an object. Objects can be of almost any shape or geometry and are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file. Unlike material removed from a stock in the conventional machining process, 3D printing or AM builds a three-dimensional object from computer-aided design (CAD) model or AMF file by successively adding material layer by layer.

In, 1984 Chuck Hull of 3D systems corporation filed his patent (4575330) (National Science Foundation, 2013) for a Stereo lithography fabrication Systems which is considered as the evolution of 3D printing technology. He stated that process as "system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed" (Wikipedia, n.d.)

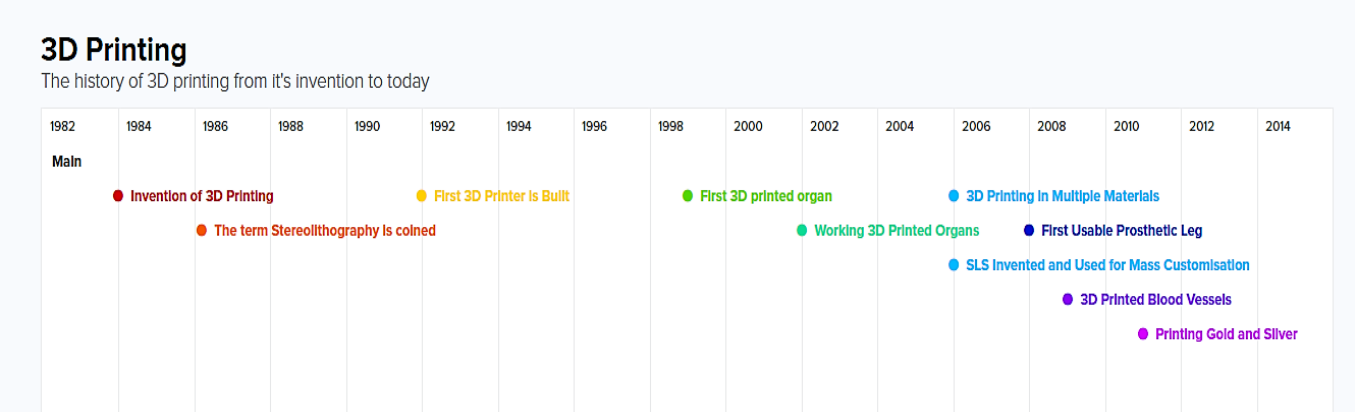


Figure 1: History of 3D Printing

2.2.2. Technologies in 3D Printing

(Source: https://3dprintingfromscratch.com**)**

There are different methods available in 3D Printing technology to build a three-dimensional object.

1)Stereolithography(SLA)

As said previously this technology was patented by Chuck Hull and this the oldest method and still being used now-a-days. This method is mostly used to make a plastic prototype. This technique requires a CAD file which contains the information about three-dimensional specifications of a structure. This CAD file is then converted into a format that printing machine can understands, this format is called Standard Tessellation Language (STL). Upon receiving this STL file the printer builds an object by liquid plastic that hardens after some time. Usually, the objects produced by this technique have smooth surface, but the quality depends on the machine used. Stereolithography is widely used in prototyping as it doesn't require too much time to produce an object and cost is relatively cheap comparing to other means of prototyping. Although this 3d printing method is rarely used for printing of the final product. Even though, this technique is very old, some companies are still using it to produce prototypes.

2)Digital Light Processing(DLP)

Digital Light Processing is another 3D Printing process very similar to stereolithography. The DLP technology was created in 1987 by Larry Hornbeck of Texas Instruments and became very popular in Projectors production. It uses digital micro mirrors laid out on a semiconductor chip. The technology is applicable for movie projectors, cell phones and 3D printing.

DLP uses photopolymers same as SLA, but what makes it different from SLA is, it uses a source of lights like arc lamps. This technique uses liquid plastic resin that is placed in a transparent resin container. This resin hardens quickly by large amount of light. This process is swift, and the end products are robust in quality and have excellent resolution.

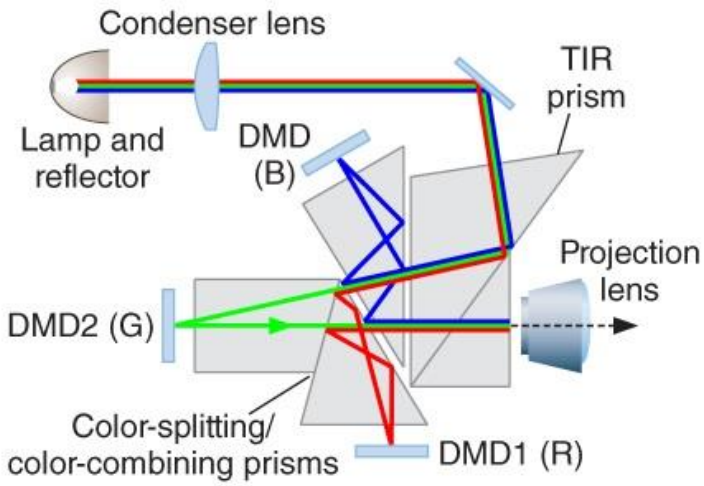


Figure 2 Digital Light processing

3)Fused Deposition Modelling(FDM)

This technology was developed and implemented at first time by Scott Crump, Stratasys Ltd. founder, in 1980s. The main advantage about this technology is that one can print not only functional prototypes, but also concept models and final end-use products. FDM is the only 3D printing technology that builds parts with production-grade thermoplastics, so things printed are of excellent mechanical, thermal and chemical qualities. FDM Technology build objects layer by layer from the very bottom up by heating and extruding thermoplastic filament.

The whole process is a bit similar to stereolithography. Firstly, special software "cuts" CAD model into layers and calculates the way printer's extruder would build each layer. Along to thermoplastic a printer can extrude support materials as well. Then the printer heats thermoplastic till its melting point and extrudes it throughout nozzle onto base, that can also be called a build platform or a table, along the calculated path. When the thin layer of plastic binds to the layer beneath it, it cools down and hardens. Once the layer is finished, the base is lowered to start building of the next layer.

Figure 3 A product developed by FDM technology

FDM technology is widely spread nowadays in variety of industries such as automobile companies like Hyundai and BMW or food companies like Nestle and Dial. FDM is used for new product development, model concept and prototyping and even in manufacturing development. This technology is considered to be simple-to-use and environment-friendly. With use of this 3d printing method it became possible to build objects with complex geometries and cavities.

4)Selective laser Sintering(SLS)

As the name suggests this technique uses laser as power source to form solid 3D objects which was developed by Carl Deckard, a student of Texas University, and his professor Joe Beaman in 1980s. This technique uses powdered material instead liquid.

Like all other methods listed above the process starts with creation of computer-aided design (CAD) file, which then needs to be converted to STL format by special software. The material to print with might be anything from nylon, ceramics and glass to some metals like aluminium, steel or silver. Due to wide variety of materials that can be used with this type of 3d printer the technology is very popular for 3D printing customized products. As this technology is very expensive, this is widespread among manufacturers.

5)Selective Laser Melting(SLM)

Like other techniques this also used CAD file which is converted into STL format and forms 3D object by means of a high-power laser beam that fuses and melts powder together. Unlike SLS, this process fully melts metal material into Solid 3-Dimensional object.

The fine metal powder is evenly distributed onto a plate, then each slice of 2D layer image is intensively fused by applying high laser energy that is directed to the powdered plate. The energy of laser is so intense that metal powder melts fully and forms a solid object. After the layer is completed the process starts over again for the next layer. Metals that can be used for SLM include stainless steel, titanium, cobalt chrome and aluminium.

This technology is wide spread where products having complex geometries and structures with thin walls and hidden voids or channels.

6)Electronic Beam Melting(EBM)

This technology was coined by Arcam AB Inc, in the beginning of this century. Like SLM, this technique uses electronic beam as power source instead of laser. EBM is rather slow and expensive, also the availability of materials is limited. So the method is not so popular though still used in some of manufacturing processes. This is mostly focuses in Medical implantations and aerospace.

7)Laminated Object Manufacturing(LOM)

This was developed by the California-based company Helisys Inc. and used for rapid prototyping.

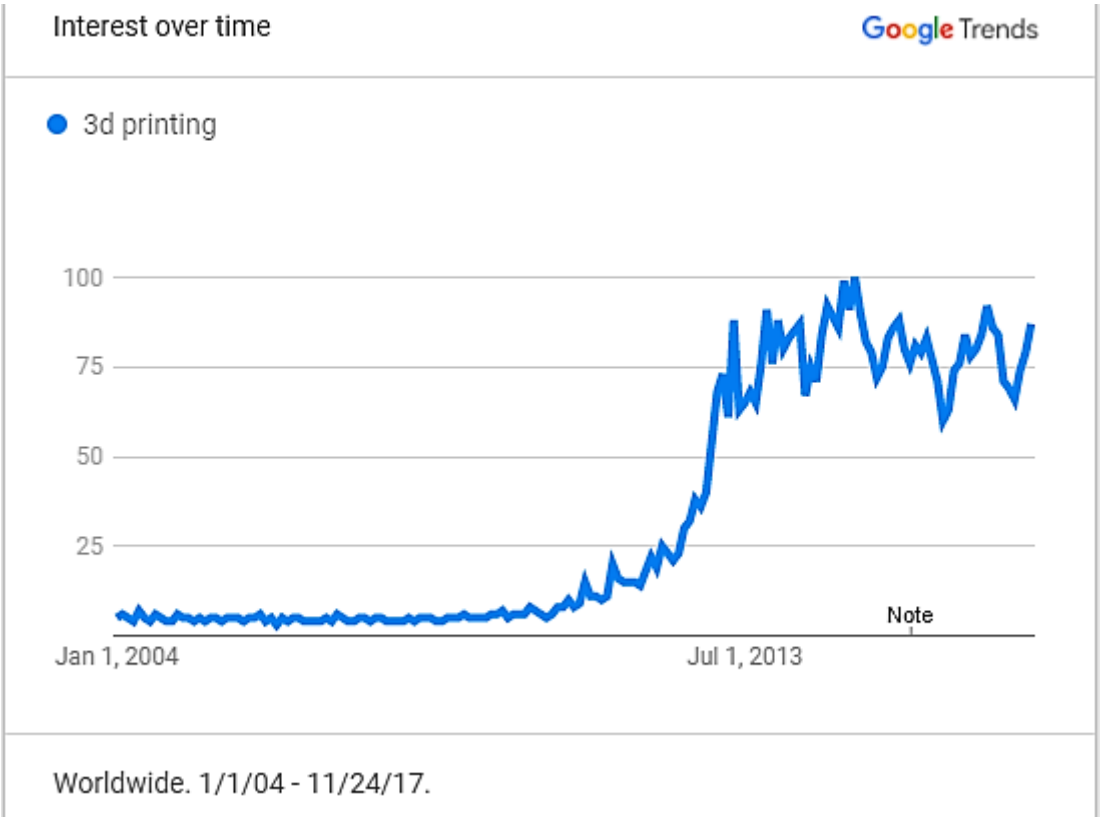
During the LOM process, layers of adhesive-coated paper, plastic or metal laminates are fused together using heat and pressure and then cut to shape with a computer controlled laser or knife. Post-processing of 3D printed parts includes such steps as machining and drilling.

First, CAD file is transformed to computer format, which are usually STL or 3DS. LOM printers use continuous sheet coated with an adhesive, which is laid down across substrate with a heated roller. The heated roller that is passed over the material sheet on substrate melts its adhesive. Then laser or knife traces desired dimensions of the part. Also, the laser crosses hatches of any excess material to help to remove it easily after the printing is done. After the layer is finished, the platform is moved down by about one-sixteenth of an inch. A new sheet of the material is pulled across substrate and adhered to it with a heated roller. The

process is repeated over and over again until 3D part if fully printed. Even though it is not popular, it is affordable due to low cost raw materials.

Since the inception of 3d printer in 1970's, it is used in large manufacturing companies mainly for rapid prototyping (bcg perspectives, 2013)and for rapid tooling. It helped companies to build and test the prototypes in a very short span. Traditional modelling techniques requires weeks or even months to build the prototypes, 3d printing technology cuts down this time to days or even to hours depending on the product. Simply 3d printer was mostly used for industrial purposes. Only the large companies could afford the 3d printers as they were very expensive and rare in the past but after the introduction of online platforms such as ponoko and shapeways in 2007 even the small companies were able to afford and use the 3d printing technologies giving them access to rapid prototyping. Bringing rapid prototyping to the masses had a large effect on the creativity, innovation and increase in competition among the companies.

By catching the interest of many companies and start up's, as the Expiration of many Patents, the number of players innovating, experimenting and producing 3d printers have increased drastically over the past decade. A chart below shows us the increasing popularity by analysing how many times the keyword "3D printing" has been searched on Google search engine over the years, where 100 represents highest popularity. As a result, the new advancements have been achieved in 3d printing technology also the prices were



Graph 1: Keyword "3D Printing" popularity on Google Trends

drastically dropped. Now a household can purchase a 3d printer for just $1000 or even less. It is worth to mention the statement by Denis Cormier, professor at Rochester Institute of Technology "**I bought one of Stratasys' least expensive models in 2009, and I paid $42,000. Now MakerBot makes something not so far off in quality that costs a little over $2,000. You now can see printers in many high schools. An average person has a chance to take their idea and make it come alive that much more**" (Cormier, 2014) that is more than 95% reduction in the prices of 3D printer in 5years.

Due to the advancements in the technology, which allowed companies to adopt Additive Manufacturing Technology Instead Traditional and to work with different materials and to manufacture products using 3d printing technology. This Adoption of 3D printing will emerge as a viable alternative to conventional manufacturing (McKinsey, 2014)

Additive manufacturing is the industrial version of 3D printing- (BCG, n.d.). It is also called as "Flexible factory in a box"- by 3D systems Inc. CEO.

To better understand the different opinions, we discussed the benefits and risks on adopting Additive Manufacturing by aggregating similar views of authors.

However, this emerging technology does not show equal threat to all industries (André O Laplume et al., 2016).

Whatever the advantages and disadvantages offered by 3d printing technology, there are different perspectives regarding this emerging technology. For example, **"Additive Manufacturing is a game changer"-** General Electric CEO, Jeff Immelt. And, by 2020, GE aviation plans to produce over 100,000 additive parts for its LEAP and GE9X Engines. Also, the company plans to invest $3.5 billion in Additive Manufacturing.

On the other hand, **"Additive Manufacturing is a gimmick and has no commercial value"-** Foxconn CEO, Terry Gou. And some others believe that 3D printing is not ready for main manufacturing for various reasons (Dillow, 2013). To discuss these different growing views on Additive Manufacturing it's good to access benefits and risks on adopting Additive Manufacturing Technology.

As noted by Schnaars (1989) technological predictions are "one of the most difficult kinds of forecast to make accurately". All the questions arising now will be addressed in the future as the technology matures.

Additive Manufacturing has the potential benefits that companies enjoy and at the same time it has major drawbacks that companies should consider before adopting.

2.1.3. Benefits Offered by Additive Manufacturing

PRODUCTION LEVEL. With traditional manufacturing, production capacity must be consolidated and centralized to achieve economies of scale, amortize up-front tooling costs across large volumes of products, and produce uniform parts at the lowest possible cost. Because 3D printers require no up-front tooling and relatively little setup time, manufacturers can move from initial design to prototype and finished product more quickly than in the past. Hence reduces the time gap between design development and development of prototype or final product, stemming the concept of **design to produce**, as there is no need to setup heavy equipment, tools or dies to produce prototype. It also undermines the concept of Economies of scale (Martin Baumers, 2015) which has been considered one of the most important reasons of off shoring. It brings out the new concept of "**Economies of One"** (Brett P. Conner, 2014). In the 3D printing economy, the need to amortize setup costs over large production runs disappears Freed from traditional economies-of-scale constraints. The additive process enables the manufacture of highly complex parts that can't be built using traditional techniques, and reduces component counts by allowing complex assemblies to be manufactured as a single part, speeding assembly times and

reducing labour costs. It also allows companies to be more resource efficient in use of raw materials and enables the design and manufacturing of efficient products (Stratsys). Converse says its ZPrinters can produce a shoe model in two hours, or nearly 30 times faster than an ABS printer. ZPrinting has also helped: Eliminate eight annual trips to Asia for design consultations at a cost of up to $12,000 per person for each trip.
Prabhjot Singh, a manager with GE Global Research, estimates that traditional manufacturing wastes up to 70 percent of purchased materials. These materials are discarded during production. Using 3D printers produces almost no waste**.** Additive manufacturing offers designers a chance to take big risks without big cost and time implications.

COMPANY LEVEL. At corporate level additive manufacturing supports in cost reduction. This reduction in costs can come from reduction in production costs, logistics costs including inventory costs, space costs. Spare parts and inventory are one of the areas that's the most advanced right now because of the value of having 3D printers in remote locations. With the advantage of Economies of One, companies can enter into new markets or even to new industry, as the cost and time of entry or exit is relatively very low (Mckinsey Quarterly). This all-in turn helps in having high profits. Also, it helps companies to lower their reliance on their suppliers, impacting the suppliers power in porters five forces. 3D technologies enabled the design and manufacturing industries to rapidly try and test ideas which significantly increased the speed of product innovation. This new technology also changing the business models, as most of the existing business models rely on mass manufacturing and totally cost-driven but not value driven. The traditional business models do not get second chances and often companies choose to learn from the failures of the competitors but with the 3D technologies it is made possible for the companies to try various business models with much lower costs. Furthermore, business models would become fully mobile and can move up/down or sideways as needed.
The recent foray of toy manufacturer Hasbro into the 'grown-ups' market provides a good example of 3D printing enabling to rapidly prototype and test business models. Hasbro became progressively aware of a rather unexpected growing fan base of adults (including males, who refer to themselves as 'bronies' — or 'bro ponies') (Watercutter, 2011). Hasbro chose to begin with a very 'short' business model. Not only did they not manufacture the products, they did not design them either. Instead, Hasbro called on fans to upload their own designs of Little Pony figurines, submissions that were screened by Hasbro before being made available on the Shape ways platform. Hasbro even let designer-fans choose themselves the price of the products, while taking a cut on the proceeds. Hence most of the exploratory work related to this new venture has been done by fans themselves.

MARKET LEVEL. As time gap between design development and prototype development is drastically reduced, the time-to-market is gradually reduced, reaching the market/s on time. For example, a 20-part aerospace subassembly welded into final form can have a lead time of up to 14 months. An AM replacement, however, can be made in less than 1 month—with 90% less scrap (BCG, 2017). The introduction of 3d printing has brought down the time to create a prototype from weeks to days or even hours therefore effecting the value proposition by speeding up new product release. But when it comes to value creation and value delivery it has a very little impact and in case of value capture it has changed the cost structure thus helping in some cost reduction. 3dprinting allows companies to "mass-customize" at relatively low costs as there is no need to change tools or dies or any other manufacturing equipment. It can produce endless varieties of products at same cost. Additive Manufacturing also used for so-called "bridge manufacturing", i.e., a first small series of product to launch it on the market. After product demand rises, more "traditional" manufacturing technologies are implemented (Berman, 2012). The introduction of 3D technologies not only bring changes in value proposition but also improve value delivery and even the smallest target market becomes economical by making each consumer a distribution channel. 3D printing may bring positive feedback loop between value creation, value proposition and value delivery.

It will change the cost of bringing new products to market. Production machines can switch between different parts as fast as operators can load a new 3D design file and feed in the raw materials, giving manufacturers unprecedented levels of agility and flexibility.

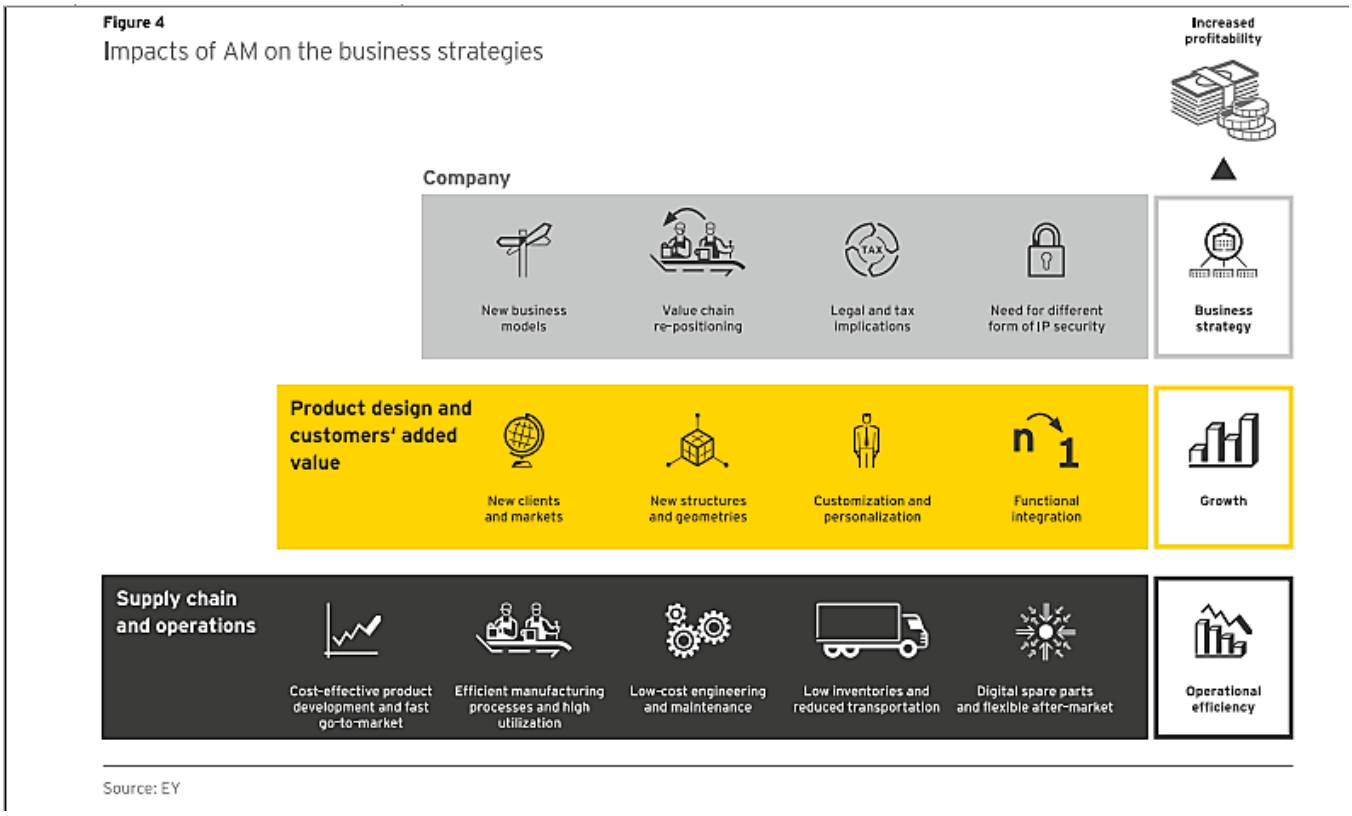


Figure 4: Impacts of AM on Business Strategies

2.1.4. Drawbacks of Additive Manufacturing

PRODUCTION LEVEL. As still this emerging technology is in development stage, the existing 3d printers can produce products with limited material like plastic, which in turn, the produced products are of lower quality and strength. Also having only single injection pointer, it is not possible to produce products made of different materials simultaneously. Also, in the industry where volume is of great importance like food industry, this technology provides no added value.

COMPANY LEVEL. The growing number of free online platforms like RepRap, Thingiverse which houses more than million designs (Wittbrodt, 2013), where consumers can download designs and print at home, imposing a great threat to the Intellectual property rights, which is to be addressed. By changing the design partly, the consumers or online platform providers can deter the IP rights (Bradshaw et al., 2010)

Recent work shows that 3D printing is economically viable for US households (Wittbrodt, 2013).As they adopt the technology, households and 3Dprint shops may gain a bigger share of potential industry earnings (Dedrick, 2010) because

3D printing puts the means of production back in their hands and undermines some of the complementary asset advantages of MNE'S.

Direct manufacturing enables large scale mass customisation resulting co-creation process between customers and firms significantly higher but successful products can be easily copied by other companies making good revenue model findings difficult. Business model innovation will be most critical and may involve radical changes in the profit allocation due to sharp increase in competition. The companies will be forced to change the business model completely and move towards more value-added products or derive revenue from complementary services. Hence the impact of 3D technologies in direct manufacturing create challenges related to the value capture that require changes in the communication component.

MARKET LEVEL. The gradual decrease of 3D printer prices allowed end consumer to have one at home beside the desktop and at the local retailers who can print the products on demand. This gives local suppliers/ companies power to reach the market as early as possible at lower cost. Also, the problem of product imitation will be a great threat. Eliminating tooling costs and using the same machine to manufacture many different types of parts are lowering barriers to entry across many industries, enabling new competitors to enter markets with great speed and agility—and far less up-front investment. small companies will become even more disruptive.

2.2. SECTORS 3D PRINTING WOULD AFFECT THE MOST

"The industries that are going to be impacted the most by 3D printing are those that are capital intensive eliminating needless costs and saving time"- Ryan Pickens, Senior Systems Engineer. Delphi Automotive

The impact of 3d printing will be in all the sectors in the future but the most impacted sectors would be health care, aerospace and automotive.

HEALTHCARE SECTOR

The health care sector is already seeing the benefits from the 3d printing. With the help of 3d printing technology it is made possible to print the parts of human organs with a very low cost. According to many experts it is believed that in the future human organ transplantation would be affordable to all people with less cost with the help of 3d printing technology. This would be significant move forward for humans in terms of medical and health.

AEROSPACE

3D printing is helping to create more efficient processes in the aerospace sector, says Robin Wilson, lead technologist in high-value manufacturing, at Innovate UK. Aircraft manufacturers have invested billions in developing the use of metal powders through this technology to make turbine blades, jet engine combustion nozzles and structural parts. Additive manufacturing—the industrial version of 3-D printing—is already used to make some niche items, such as medical implants, and to produce plastic prototypes for engineers and designers. But the decision to mass-produce a critical metal-alloy part to be used in thousands of jet engines is a significant milestone for the technology. And while 3-D printing for consumers and small entrepreneurs has received a great deal of publicity, it is in manufacturing where the technology could have its most significant commercial impact. The impact of 3d printing is also being felt on defence sector. The parts for the defence sectors are not yet being printed but the future looks more promising to use the 3d printing technology in vast areas of the defence as well.

AUTOMOTIVE

Motorsport is making use of the technology to produce parts for development models, test and racing cars. They are also exploiting it to bypass very long lead manufacturing processes, such as tooling for composites, to allow direct manufacture. It is changing the way to design, develop and manufacture new things in the automotive industry. In the automotive industry, those technologies have made wonders to bring new shapes to life, allowing for lighter and more complex structures at the best possible cost. While it remains true that 3D printing is still mainly used for rapid prototyping when developing new models or in concept cars, the evolution of the different AM technologies has led a way where it is also used for final parts in various situation. New materials, innovative finishes, shorter lead time now allow for 3D printing to be integrated more closely in the manufacturing process and in the future maybe in the supply chain for spare parts.

Construction sector

AM will make it more sustainable. Additive manufacturing fits with the construction industry’s desire to be more sustainable and efficient by creating only the amount of materials needed, cutting down on waste, and also on unnecessary labour costs. We have already seen the movement in the 3D printing home space. Typically, concrete extrusions are used for building materials. Advanced engineering applications may use metal based materials, like titanium

and steel, but simply for durability and accessibility, current architectural practice is more amenable to concrete based printing.

Industry/Product	Firms	Firm's home country
Aerospace	Boeing	USA
	Lockheed Martin	USA
	Aurora Flight Science	USA
	General Electric Aviation	USA
Automotive (including parts)	Red Bull F1 team	Austria
	BMW	Germany
	Honda	Japan
Camera lens accessories		
Construction		
Electronics (including PCs)	Google (for outsourced consumer electronics products)	USA
Filter and filtration solutions	Anonymous company	UK
Food processors (replacement parts)		
Footwear	Timberland	Turkey (at the time Italy)
Household (replacement parts)		
Houseware	Alessi	Italy
Lighting	LUXeXcel	The Netherlands
Medical & dental applications (e.g. Dental crown, Hearing aids molds, Prosthetic limbs)	Align Technology	USA (worldwide HQ Netherlands)
	Anonymous company	Germany
	Anonymous company	Switzerland
Measurement devices		
Sunglasses		
Telecom infrastructure		
Wallpaper	Anonymous company	UK

Table 1 3D adopting industries and companies

2.3. How companies can assess 3D printing for their supply chain

Below we discuss various ways that companies can leverage 3D printing in the supply chain to increase operational excellence as well as to improve the customer experience. To understand the implications of additive manufacturing in a company's supply chain it is necessary to understand the company's operating environment, manufacturing capability, customer needs, and product portfolio of each company. If the companies believe they have high relevance of 3D printing in their manufacturing and supply chain strategies they can assess and map the 3D printing journey. In order to do so the companies could follow the path as below.

1)Analyze the products and organizational capabilities

The first thing the companies need to do is to look into their organization to assess current 3D printing capabilities and identify where there are any gaps and whether there's a need to bring in external expertise. Once this is done companies can begin to analyze their current and future product portfolios in order to identify products that can be 3D printed and/or could benefit from 3D printing technology. For example, could 3D printing enable new product geometries that are more efficient? Or could 3D printing enable new personalization options that would deliver additional value to the customer? Once this list has been developed, the next step is to prioritize products based on suitability for 3D printing and the benefits that can be achieved from 3D printing. Companies should prioritize highly complex and customizable products over generic items that have no inherent need for customization. An additional aspect could be to prioritize products that are currently produced in small batch sizes, such as spare parts.

2)Create their own transformation roadmap

From the gap analysis of 3D printing capabilities in the organization and from the prioritized list of products (step 1), companies can then develop a step-by-step roadmap to successfully transform and integrate 3D printing into the organization. This can be achieved by assessing the near-term and long-term feasibility of 3D printing in the manufacturing supply chain (in terms of a business model based on material and printer costs, time for production, quality, etc.). It is valuable to engage with a logistics provider in this step to factor in the logistics implications as well as potential new ideas for savings and innovative business models.

3)Adapt and implement 3D printing into the company's manufacturing supply chain

The final step is to adapt current manufacturing and supply chain strategies and ensure successful integration of 3D printing into the organization. Companies need to focus on working together with partners to redesign and optimize the manufacturing supply chain (e.g., to establish a network to leverage spare parts on demand or to utilize end-of-runway services). As 3D printing is a fast-developing technology, today's technology investments will probably be outdated in just a few years' time. So, it makes sense to start with several pilots with the most promising product segments and then move towards a full-scale transformation and implementation as the success factors in chapter one is achieved. At this stage, companies should also continuously build up their organization's resources and capabilities to embrace 3D printing.

The industry adoption of 3D printing is still very limited. Based on the data available we found that though companies are excited about the prospect of 3D printing in future not a lot of companies have moved from traditional manufacturing to 3D printing. It was thus really challenging to make assumptions around the industry adoption numbers. It is very difficult to predict how 3D printing cost structure will change over the next 5-10 years. This is especially related to the cost of 3D Printer and the raw material used. With the rapid advancement going on in 3D Printing technology it is difficult to predict what type of product can or cannot be 3D Printed in future. Design for 3D Printing is in nascent stages at this stage it was fairly difficult to quantify this. It is quite challenging to predict how 3D Printing will displace traditional manufacturing and what will be the quantitative impact of this change.

However, that is not to say that 3D printing will not be disruptive. 3D printing is likely to substitute traditional manufacturing in industry segments that produce highly complex and customized goods. This is, in fact, already happening in aviation, automotive, and medical and healthcare applications. To achieve wider application and adoption, companies must collaborate and innovate in order to overcome 3D printing's remaining challenges – such as speed of production, cost, and limited material inputs.

Much of the existing literature on additive manufacturing is related to the technical properties and capabilities, only few authors have focused the attention on its impacts on International Business and the possible impacts of additive manufacturing on global business landscape. Data are still fragmented and mainly focused on sample of firms in specific countries. Additionally, there is no coherence among the authors about the future happenings due to 3d printing technology.

For this reason, we followed an explorative research methodology through the analysis of case studies, starting from examination of several views proposed by different authors. This first stage of work allows us to establish some hypotheses and patterns of future Business landscape in the additive manufacturing era.

3.Changes in the Global Value Chain:

There are several areas where additive manufacturing has been imposing great effects, below we state and discuss some of the most important areas which are highly discussed by authors and of high importance to our topic.

3.1. offshoring vs Reshoring

Off-shoring has been a significant topic in International Business. Over a century MNE's have been off shoring their Manufacturing process (Fratocchi,2017) or even some of their Business functions and services like customer service call centres. These off-shoring activities are mostly focused towards eastern countries like India, china, Bangladesh etc. The driving force behind this phenomenon is mostly the low-cost labour provided by these emerging countries. Manufacturing cost in these countries outweighs the transportation costs. Also, advent of Information Technology bolstered this international fragmentation of business activities. These activities are relatively low added value operations.

But after experiencing decades of offshoring, some companies have started to bring back their activities to their home country (Filippo Albertoni, Stefano Elia, Luciano Ftracchi, & Lucia Piscitello, 2015).

As, 3D printing is considered as disruptive technology as like digital books and music downloads (Berman, 2012), it allowed companies to reshuffle in their production locations & Production strategies in four ways (Gray, Reshoring Phenomenon: What supply chain academics ought to know and should do, 2013).

Ken Cottrill in his article titled "Reshoring: New Day, False Dawn, or Something Else." divides reshoring into four categories:

"**In-house reshoring** refers to the relocation of manufacturing activities, which were being performed in facilities owned abroad, back to facilities in the U.S."

General Motors (GM), for example, announced plans to move the full production of its Cadillac SRX sport-utility vehicles to its Tennessee factory from the GM factory in Ramos Arizpe, Mexico. On a smaller scale, GM also plans to move the production of the electric drive unit for the Chevrolet Volt from Ramos Arizpe to its factory in Michigan. The production of all other parts for the Volt will remain abroad.

"**Relocating in-house manufacturing** activities, which were being performed in facilities abroad, back to U.S.-based suppliers, is labelled “reshoring for outsourcing.”

Outsourced reshoring describes the process of relocating manufacturing activities from offshore suppliers back to U.S.-based suppliers.

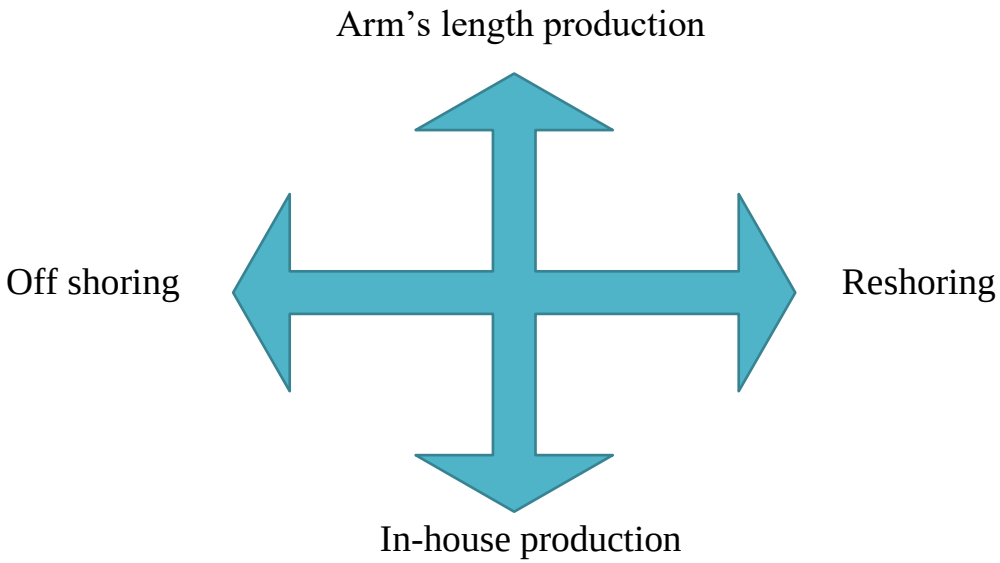
For instance, General Electric decided to relocate the production of its GeoSpring water heater from a Chinese factory back to the company’s Appliance Park in Louisville, Kentucky. GM CEO Jeffrey Immelt believes that outsourcing is “quickly becoming mostly outdated as a business model for GE Appliances.” Since 2009, the company has made increased efforts to streamline its manufacturing at its Appliance Park. As of year-end 2014, the park was expected to employ 3,600 hourly employees—more than twice the amount as of 2013—500 of which are new designers and engineers hired to support the new manufacturing.

Reshoring for Insourcing is "when a company relocates manufacturing activities being outsourced to offshore suppliers back to its U.S.-based facilities, it is considered reshoring for insourcing." In this case, the firm still outsources

parts of its manufacturing operation; but, instead of outsourcing overseas, the company contracts with U.S.-based suppliers.

This reshuffling is discussed below.

These changes might take place between two extremes. One extreme is reshoring production to home country, and on other hand more diversified off shoring, i.e., highly fragmented global value chain (GVC). Following, companies might choose production strategies i.e., whether to produce in-house or arm's length production (Make or buy decision).



As stated by Chen & Kamal, 2016 "codifiability of production process plays an important role while making decision whether to make or buy". Multinational companies in which production processes are easily codified into electronic format, have proclivity for arm's length production". As, even though the production of products using 3d printing is additive, design and other production processes are to be converted into electronic format. This easy codifiability of production processes helps companies to fragment production process among different suppliers. Another aspect of this fragmentation is that it may help companies to mitigate the risk of leakage of intellectual property as the information is shared among large number of suppliers and it may help companies to work for more diversifies production (Kamal, 2016). 3D printing may facilitate outsourcing. (Berman, 2012)

Regarding the production location changes, it can be verified by (Berman, 2012), stating "Additive manufacturing have impact on decisions taken regarding manufacturing location relatively low fixed costs for basic additive manufacturing machines and setup, combines with the feasibility of economically producing small batch sizes, will potentially enable local production near or even at the point of use". According to him additive manufacturing enables companies to outsource the production activities because the designs are easy to share.

The presence of production activities in the same point of sale/use/distribution i.e., Home fabrication, could be the companies' new "mantra" for mass customization, allowing companies to charge premium price at very low production cost and with reduced or without inventory costs. The footwear industry may be a perfect example for this scenario. Adidas is working towards this business model. Company said, "Imagine walking into an Adidas store, running briefly on a treadmill and instantly getting 3d printed running shoe- this is the ambition of the Adidas." Stated by (RuthJiang, 2017), Companies no longer needed to forecast demand and producing it on stock, but all the production activities are purely reactive i.e., produce on demand. Adidas change in business model is a perfect example for this future scenario.

3.2. Home Fabrication

A greater number of 3D printer adoptions are expected as it brings changes in the value proposition that leads to changes in the value delivery. The cost structure is expected to be improved even further as the customers solely bear the manufacturing and distribution costs. The impact of 3D technologies is disruptive in this case as the consumer engage in the co creation activities and the companies will be forced to rethink both of their revenue models and profit allocation.

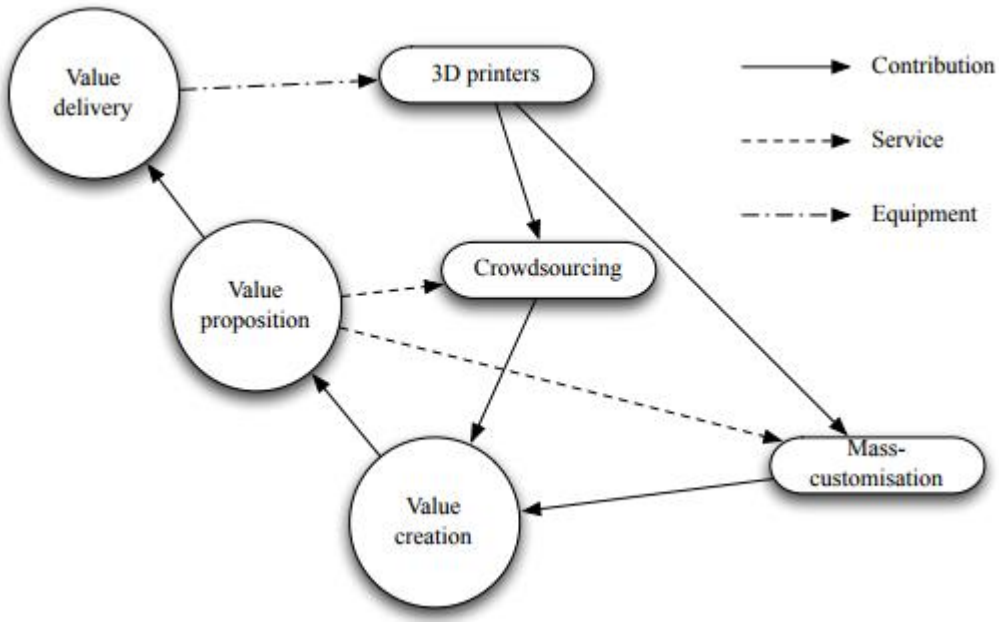


Figure 5 Home fabrication

In addition to this, Other literature contributions focus the attention on Re-shoring scenario. After the development of ICT and changes in the economic environment globally, emerging countries like India, China, and other Eastern countries provided companies with low cost labour and production, hence production in these countries outweigh the transportation cost. To take advantages of these lower production costs, most of the companies off-shored their business activities to Eastern countries. These activities are mainly the production of low added value goods and sometimes, customer service, call centres, and financial and accounting services etc. While the previous 10-15 years were defined by outsourcing and off-shoring looking for low cost alternatives for manufacturing activities, the rise of 3-D printing and cheaper energy domestically will cut into the overhead costs of manufacturing, and shrink labour costs, as a capital and skill-intensive technology. The advantage in emerging markets may swing the pendulum back to domestic sourcing in the advanced countries.

This possible scenario may offer several advantages. A local supply chain offers greater protection of intellectual property and a better ability to manage quality control. Although there might be several other reasons for reshoring, like high rise in wages in countries like China and India, fierce competition from local players, government regulations etc, additive manufacturing is acting as a catalyst. Taking the example of Nike, which was previously mainly focused on design and offshore production activities to Eastern countries. Now, with the help of additive manufacturing Adidas and Under Armour are currently investing heavily in relocating manufacturing from far East to Western Markets.

Manufacturing in factories is efficient for mass produced products that have low variety. But for a lot of companies, the market is shifting, and companies need to redesign manufacturing to become more flexible, data driven and able to achieve cost-efficient production across a large range of volumes. As stated in Ruth Jiang, Robin Kleer, Frank T. Piller writing, "Making spare parts using additive manufacturing will simplify logistics, and is a need for companies with time-critical service contracts". So, in industries where penalties for late delivery or the value loss due to unavailability of products, matters drives for locally installed Additive Manufacturing Machine. We have an example for this scenario, Tesco is exploring potential utility of having 3D printers in its stores to produce spare parts on demand.

The 2014 PwC survey, involving more than 100 companies shows that the 11% of those firms already switched to volume production of 3d printed parts or products and this percentage will increase soon, as the sales of industrial grade 3D printers are increasing.

3.3. Direct manufacturing

As the technology matures and becomes more widely accepted, new business models emerge (Sabatier et al., 2012). Direct manufacturing has the potential to disrupt the business models than the rapid prototyping and rapid tooling. The cost of manufacturing with 3d technologies still remains higher than the traditional manufacturing but the companies which are following the 3D technologies are trying to leverage on the unique advantages that the 3D technologies can offer. When it comes to the impact of 3D technologies on the components direct manufacturing has an impact on value proposition as it improves product and service offerings and it enables full customisation and new pricing models.

Direct manufacturing enables large scale mass customisation resulting co-creation process between customers and firms significantly higher but successful products can be easily copied by other companies making good revenue model findings difficult. Business model innovation will be most critical and may involve radical changes in the profit allocation due to sharp increase in competition. The companies will be forced to change the business model completely and move towards more value-added products or derive revenue from complementary services. Hence the impact of 3D printing technologies in direct manufacturing create challenges related to the value capture that require changes in the communication component.

The ability and the extent to which the firm is able to create, and capture value is defined by its business model (Øiestad and Bugge, 2014). As noted in Baden Fuller and Morgan (2010) business models are often hard to define, since they can serve at the same time as scale models, role models and ideal models. Although there are differences amongst scholars about what constitutes a business model, there is a broad consensus around four critical components: value proposition (Voelpel et al., 2004; Casadesus-Masanell and Ricart, 2010; Chesbrough, 2010; Teece, 2010), value creation (Zott and Amit, 2002; Voelpel et al., 2004; Chesbrough, 2007), value capture (Chesbrough, 2007; Holm et al., 2013), and value delivery (Osterwalder et al., 2005; Abdelkafi et al., 2013; Holm et al., 2013). A fifth component, value communication, is also often considered as a critical aspect of a business model (Abdelkafi et al., 2013)

Figure 6 Business models in 3D printing

3.4. The rise of 3-D printing is disrupting traditional supply chains and locational advantages of low cost countries

A significant proportion of the world's manufacturing is the result of an international division of labour co-ordinated by MNE'S (UNCTAD, 2013)From 1960's due to tax-exempt and tariff-free export production zones in most of

developing countries, US multinational companies began offshoring (André O Laplume, Global value chains from a 3D printing Perspective, 2016). In 1980s, this coordination of division of labour was labelled as "global value chain" by Porter, 1985 in which he describes the sophisticated global specialization of the various value-chain activities of multinational companies. Additive manufacturing is threatening that labour cost advantage. The improvements in automation and efficiency will decrease production costs and compel manufacturers to reassess the cost-benefit trade-off of off shoring. As Advanced Manufacturing allows for the establishment of micro-factories that leverage local talent, the democratization of manufacturing could slow the trend to more globalization of markets. This might already have played a role in the slowdown of global trade observed in the last few years. The Democratization of Manufacturing may also be impacting China's dominance as a manufacturing hub. A 2015 poll conducted by Boston Consulting Group of U.S. manufacturers with sales of at least $1 billion found that 53% of companies are considering bringing production back from China, up from 37% in 2012. Seventeen percent of respondents say they are already in the process of reshoring, up from 7% in 2012. These executives felt that logistics, inventory costs, ease of doing business, and the risks of operating extended supply chains are the factors impacting their decision. Low wage costs will not have as large an impact for AM industries, threatening advantages that some export-driven countries have maintained. Instead several factors will weigh more heavily on factory location decision making: proximity to the supply chain and customers, availability of skilled labour, energy cost efficiencies, quality of overall infrastructure, and an environment more conducive to business. The implications democratized manufacturing will have on supply chains is uncertain, but if the vision of localized sourcing becomes a reality, export-driven economies could feel the impact.

In traditional manufacturing, each part of a machine or a product is needed to be built somewhere as safely and inexpensively as possible with numerous intermediate production steps and all these individual parts are needed to be transported and assembled somewhere far away from the point of consumption. With 3D printing technology it is possible going directly from digital design to a final component, with no intermediate production steps (Stratasys). 3d printing may also enable the convergence of traditional supply chain and new ownership models, where design, manufacture and retail become co-located. The increased use of 3-D printing, or additive manufacturing, will transform the supply chain. The 3-D printer can be housed in a much smaller factory (or even garage) as opposed to a traditional manufacturing line.

As stated previously, this technology was only used only for high-end manufacturing, prototyping and desktop 3D printing remained a pursuit of hobbyists, innovators and early adopters (André O Laplume et al., 2016). But,

now the technology appears more economical than more labour-intensive “cut-and-mold” manufacturing techniques, as the prices were dropped drastically. This allows “personal fabrication and peer production which will replace most industrial process.

Authors are divided into two extremes, as described previously, more diversification of global value chain and shrinking in value chain. In the first scenario, production activities move much closer to the end customer, as of now, there is no much empirical evidence for this scenario. US based start-up Techshop and established players like logistics company UPS or the French La Poste provide local Manufacturing capacities, such that small business and consumers alike can produce 3D design in a local shop, evolving the concept of PROSUMERS (Kothman and Faber, 2016; Mohr and Khan, 2015). Additive Manufacturing is changing the way of doing business, UPS is building on its existing third-party logistics business to turn its airport hub warehouses into mini-factories.

The concept of “global virtual value network” had been evolving (Stratasys). Headphone Manufacturing company Normal ears is also changing the way consumers engage in the retail value chain by turning 3D scanning and 3D printing of personalizes headphones into a retail experience by moving manufacturing into the shopping mall.

The latter, is the scenario, where companies are looking to shrink their global value chain, so that their reliance on their suppliers will reduce. And helps them to speed up the product launch into market. Also, the costs. For, example, Lamborghini’s prototyping requirements are previously outsourced, operations were brought in-house in 2007 with the installation of Stratasys Dimension, 1200ES 3D printer (Stratasys, 2015).

A sample 3D printing Value chain (Gershenfeld, 2008; Moilanen & Vadén, 2013; Lipson & Kurman, 2013). The map exhibits that additive manufacturing shows its effects not only on Companies but also on its suppliers and customers (Fratocchi)

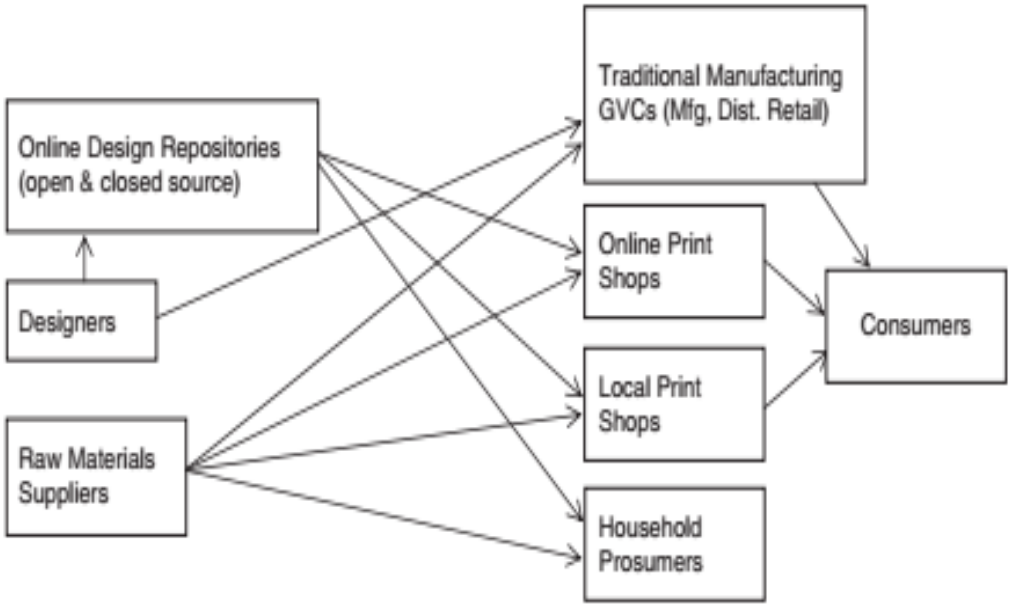


Figure 7:Sample 3D Printing value chain

Prior to the 2009 global financial crisis, global trade used to grow at about twice the pace of global GDP; after 2009 it has been growing at just the same pace, and even slower over recent years.12 More research is needed to fully understand this phenomenon, but some analysts believe that new innovations such as advanced manufacturing might be playing a role. With localized suppliers and distribution, the existence of a global supply chain existing as we know it could be threatened. While this has the potential to create a greater number of jobs locally, export dependent countries may need to accelerate efforts to rebalance economies to a healthier differential between exports and services.

"Digital innovations of advanced manufacturing will augment the capabilities of workers at different levels of the skills distribution. Different and better skills will be needed, but technology itself will help in the process." — (Marco Annunziata, Chief Economist, GE).

3.5. Acquisitions and collaborations in 3D Printing area

Multinational Enterprises (MNEs) used to collaborate with other giants in the same industry. With the emergence of Additive Manufacturing, MNE's are approaching companies who are ahead in Additive Manufacturing technology. Adidas, is partnering with Materialise. It was founded in 1990 by Wilfried Vancraen as a spin-off of the KU Leuven, and was the first Rapid Prototyping

Service Bureau in the Benelux region. Materialise will be creating Mid-soles for Adidas.

The other scenario, is General electric bought a controlling stake in Swedish 3D printing company Arcam AB, founded in 1997 and Germany's Concept Laser and launched an additive Manufacturing division.

These kinds of behaviour by MNE's reveals their concept of "Wait and see Strategy" so by playing a safe game. MNE's are allowing start-ups to invest and innovate 3D printing and Acquiring them when they become matured. Given a steep learning curve and a scarcity of experienced engineers and technicians, industry players may have to consider acquisitions to enter the metal AM space.

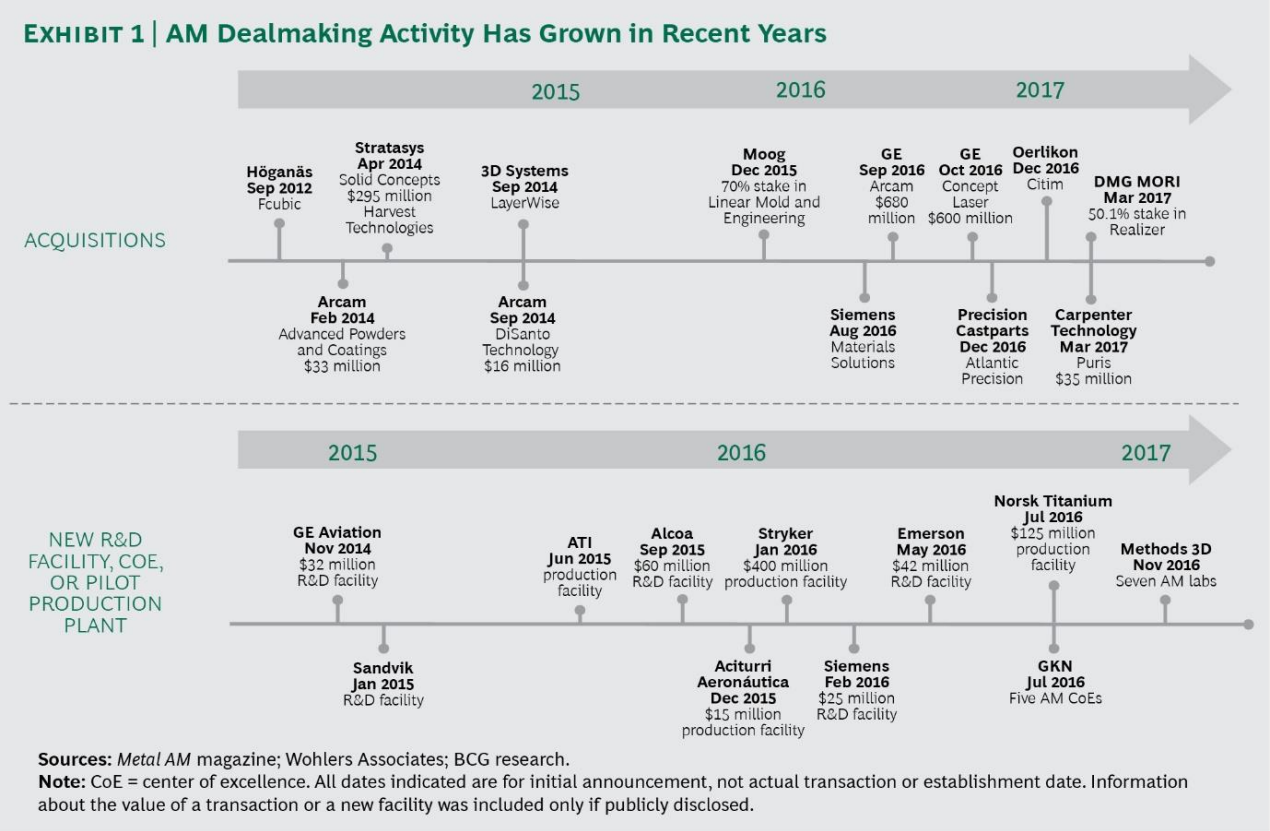


Figure 8:AM deal making activity

3.6. The rise of 3-D printing and robotics is disrupting traditional supply chains and distribution channels.

The increased use of 3-D printing, or additive manufacturing, will transform the supply chain. Offshore labour has been cheap enough to more than offset the cost of shipping parts across the globe. Additive manufacturing is threatening that labour cost advantage. Also, in traditional manufacturing it is necessary to build

several components that perfectly fit together to form the finished part or product. Additive manufacturing has shifted the paradigm. A part that traditionally needed several components can now be designed onscreen and printed out to the exact specifications needed.

The 3-D printer can be housed in a much smaller factory (or even garage) as opposed to a traditional manufacturing line. These improvements in automation and efficiency will decrease production costs and compel manufacturers to reassess the cost-benefit trade-off of off shoring. As Advanced Manufacturing allows for the establishment of micro-factories that leverage local talent, the democratization of manufacturing could slow the trend to more globalization of markets. This might already have played a role in the slowdown of global trade observed in the last few years. Prior to the 2009 global financial crisis, global trade used to grow at about twice the pace of global GDP; after 2009 it has been growing at just the same pace, and even slower over recent years.12 More research is needed to fully understand this phenomenon, but some analysts believe that new innovations such as advanced manufacturing might be playing a role. With localized suppliers and distribution, the existence of a global supply chain existing as we know it could be threatened. While this has the potential to create a greater number of jobs locally, export dependent countries may need to accelerate efforts to rebalance economies to a healthier differential between exports and services.

The Democratization of Manufacturing may also be impacting China's dominance as a manufacturing hub. A 2015 poll conducted by Boston Consulting Group of U.S. manufacturers with sales of at least $1 billion found that 53% of companies are considering bringing production back from China, up from 37% in 2012. Seventeen percent of respondents say they are already in the process of reshoring, up from 7% in 2012.13 These executives felt that logistics, inventory costs, ease of doing business, and the risks of operating extended supply chains are the factors impacting their decision. Low wage costs will not have as large an impact for AM industries, threatening advantages that some export-driven countries have maintained. Instead several factors will weigh more heavily on factory location decision making: proximity to the supply chain and customers, availability of skilled labour, energy cost efficiencies, quality of overall infrastructure, and an environment more conducive to business. The implications democratized manufacturing will have on supply chains is uncertain, but if the vision of localized sourcing becomes a reality, export-driven economies could feel the impact. "Digital innovations of advanced manufacturing will augment the capabilities of workers at different levels of the skills distribution. Different and better skills will be needed, but technology itself will help in the process." — (Marco Annunziata, Chief Economist, GE)

Industry/Product	Firms	Firm's home country
Aerospace	Boeing	USA
	Lockheed Martin	USA
	Aurora Flight Science	USA
	General Electric Aviation	USA
Automotive (including parts)	Red Bull F1 team	Austria
	BMW	Germany
	Honda	Japan
Camera lens accessories		
Construction		
Electronics (including PCs)	Google (for outsourced consumer electronics products)	USA
Filter and filtration solutions	Anonymous company	UK
Food processors (replacement parts)		
Footwear	Timberland	Turkey (at the time Italy)
Household (replacement parts)		
Houseware	Alessi	Italy
Lighting	LUXeXcel	The Netherlands
Medical & dental applications (e.g. Dental crown, Hearing aids molds, Prosthetic limbs)	Align Technology	USA (worldwide HQ Netherlands)
	Anonymous company	Germany
	Anonymous company	Switzerland
Measurement devices		
Sunglasses		
Telecom infrastructure		
Wallpaper	Anonymous company	UK

(Fratocchi)

Table 2: Sectors and firms adopting AM and their home countries

In the following section, we focused our attention on Reshoring phenomenon also changes in locational advantages of low cost countries by analysing three case studies and changes in Global value chain.

4. Empirical strategy

The purpose of our analysis is going in-depth in this topic, investigating the business behaviour adopted by MNEs, with a qualitative approach.

The future happenings of effects of Additive Manufacturing Technology on doing Business, are so un clear that it is not possible to predict exact happenings as of now, as the technology yet to mature. And it is very difficult to focus on every aspect of International Business, so we will be focusing our interest on most important areas of International Business, working on following two research questions.

1)Does Additive Manufacturing is affecting the locational advantages of Low cost emerging countries? Could Additive Manufacturing encourage Reshoring?

2) How Does Additive Manufacturing Affect Global Value Chain?

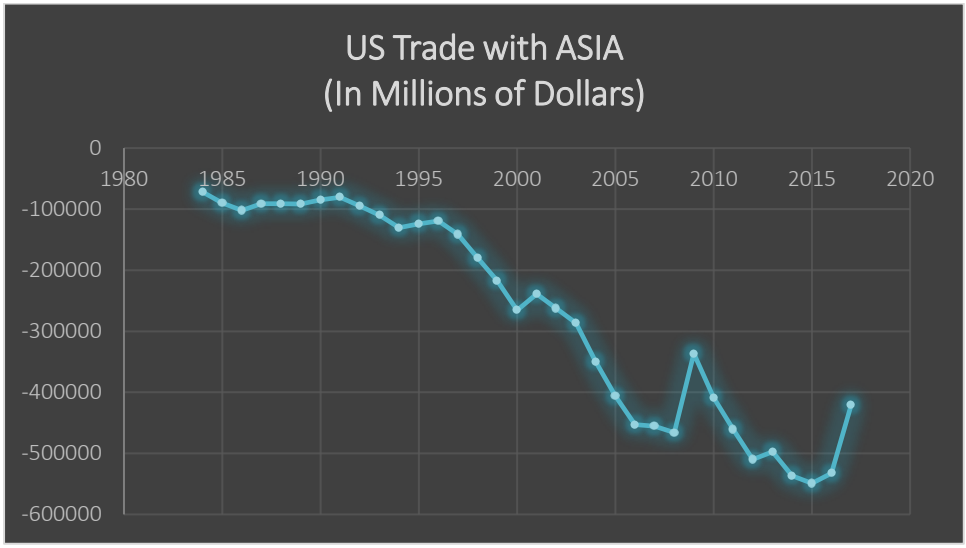
4.1. Additive Manufacturing and Locational advantages

Off-shoring is the concept of shifting of one or more business functions from home country to another country. Industrial revolutions have been impacting the way business done. The rise of jet engines and Information Technology has made the world to shrink making world as a global village and distances are just numbers. These inventions which increases the speed of transportation and sharing the information is effortless, acts as bolsters for the companies to offshore their business functions, especially back-office works like call centres etc. which generally called Process Outsourcing.

Production Offshoring or Physical Restructuring often referred to Manufacturing companies, involved in moving of Manufacturing Plants I.e., production and sometimes services to another country. Current manufacturing challenges revolve around import and export costs, lead times and a shifting market both in North America and overseas. While North America remained a hub of tooling,

moulding and large-scale manufacturing until around the late 1970s and early 1980s, offshoring large volume production has become the widespread trend of the past two decades. In a 2012 article on insourcing, The Atlantic reports, "Manufacturing jobs peaked in 1979 at 19.6 million. They drifted down slowly for the next 20 years…but since 2000, these jobs have fallen precipitously." A tool made offshore can cost anywhere from $10,000 to $50,000 less than a tool made in the states or Europe, due mainly to significantly reduced labour costs offshore and this trend accelerated as the ICT exploded (Kulkarni, 2016).

Below graph shows the balance of payments went to trade deficit. It clearly showcases how the Imports dominated US economy that leads to trade deficit with Asia since more than 20 Years.



Graph 2:US trade with Asia

In addition to industrial revolutions, there are another two important aspects that compelled companies to off shore or rely on outside service providers.

1)Low cost labour (Locational) advantages provided by emerging countries.

2)Socio-economic and political factors.

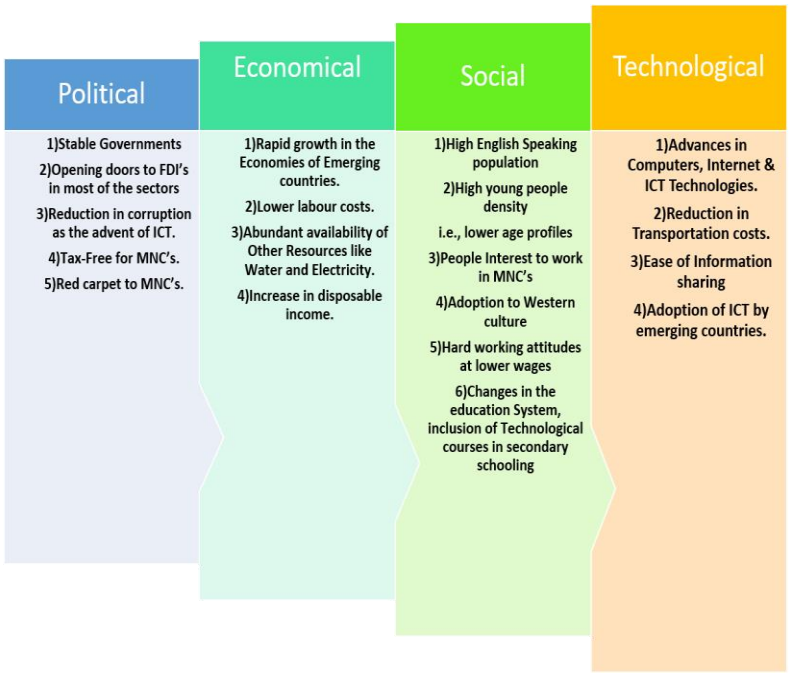


Figure 9: PEST analysis for emerging countries

By emerging countries, we not only mean eastern countries like China and India, but all emerging countries, those include Costa Rica, Mexico, Brazil or western European countries. A PEST analysis of emerging countries gives us the clear picture of reasons behind Offshoring.

To simplify, we considered the wage difference for the past 65 years between United States and China, it is obvious that there was huge difference in wages between US and Asia which was one of the driving factors for production offshoring aiming at lower production costs.

4.2. Additive Manufacturing and Reshoring Strategy

Technologies are always being evolving, which have been impacting the way of doing business and economies since centuries. Multinational Companies are always in quest for low cost production. The Locational advantages, especially low-cost labour, coupled to low production costs which outweigh transportation costs of the emerging and developing countries are eroding. The wage gap between Western and Eastern countries is narrowing.

Graph 3:Comparsion of US & China labour wages

Coupled to this raise of wages in emerging countries, there are some other important factors that making companies to rethink on offshoring and compelling them to bring back production to their home or to other countries (Changes in GVC). Primary and important reason is coupled with higher unemployment rates, stagnation in GDP induced Political pressures on companies to Reshore or to set up in America, emerging countries instead.

Reshoring is a manufacturing location decision, that is a change in policy from a previous decision to locate manufacturing offshore from the firm's home location. A definition that complements this description is: "moving manufacturing back to the country of its parent company," coined by Lisa Ellram, a professor of supply chain at Miami University.

There is a growing consensus about Reshoring:

"We're going to get Apple to start building their damn computers and things in this country instead of in other countries," Trump said at a campaign rally.

At the 2013 National Retail Federation Expo, Walmart's U.S. CEO Bill Simon explained, "manufacturers have…defined the "tipping points" at which manufacturing abroad will no longer make sense".

Walmart's U.S. Manufacturing Innovation Fund was launched in 2013 as the company's long-term strategy to help revitalize U.S. manufacturing through

a commitment to buy an additional $250 billion in products that support U.S. jobs by 2023.

A month after Donald Trump was elected president, Taiwan-based Foxconn was one of the first companies to announce plans to invest billions to help create jobs.

After U.S President Donald Trump pledged to put “America First” in his inauguration speech, Foxconn announced to invest exceeding $7Billion in US in setting up a display-panel unit, said by Foxconn company chairman and chief executive, Terry Gou. While his speech he stated an important aspect about United States that America has no panel-making industry, but the world’s second largest market for television. Although the investment expected to create 30,000-40,000 jobs, but due to the fact as the unit is going to be automated it might create only 5,000-10,000, also it is considered in setting up some sister units in and around US that will use the panels to make computer and TV screens for its sharp brand, making it a total of around $10 Billion investment. Al though there might not be any patriotic view behind this investment, but Foxconn wants to be close to the market, to this strategic decision advancements in technology helped them to announce in the investment. The difference in expected jobs creation and real creation clearly shows us the technological reason behind the investment.

Before Trump, Obama has also taken “Insourcing Initiative” to bring back jobs that offshored so far.


The White House
Office of the Press Secretary

For Immediate Release January 11, 2012

President Obama Issues Call to Action to Invest in America at White House "Insourcing American Jobs" Forum

Figure 10 insourcing initiative by Obama Source: https://obamawhitehouse.archives.org

In prepared remarks, **President Obama** said, "Today…. That's exactly the kind of commitment to country we need – especially now, at this make-or-break moment for the middle class. And I'm calling on those businesses that haven't brought jobs back to take this opportunity to get the American people back to work. That's how we'll rebuild an economy where hard work pays off and responsibility is rewarded – and a nation where those values live on."

These initiatives compelled companies to insource manufacturing back to US. Taking Ford as an example, Ford's competitive labour agreement with its UAW partners is making it possible to build small cars profitably in the U.S., invest $16 billion here at home, and add 12,000 jobs in U.S. plants by 2015. In fact, Ford is insourcing jobs from China, Japan and Mexico. Instead of adding production for the Fusion in Mexico, Ford is planning to bring that additional work to its Flat Rock plant in Michigan. This insourcing effort will ensure the viability of a key assembly plant in the U.S. and add over 1,200 new jobs. Also, Ford has committed to in-source the production of F-650 and F-750 commercial trucks from a joint venture in Mexico to Ohio Assembly Plant in Avon Lake, Ohio. This will make Ford the first auto manufacturer to produce Class 6 and Class 7 trucks in the U.S. and help retain nearly 2,000 jobs in that plant.

Master Lock is the world's largest manufacturer of padlocks and related security products. Since mid-2010, Master Lock has returned approximately 100 jobs back to Milwaukee, Wisconsin that had previously been off-shored. The decision to bring these jobs back was partially motivated by economic reasons related to increasingly higher labour and logistics costs in Asia, and further, ongoing labour availability challenges especially in the coastal areas of China, which have negatively impacted continuity in supply to its key customers. Master Lock plans to continue bringing jobs back to Wisconsin, citing a more competitive overall cost structure, greater control, and the ability to provide better service to its customers.

However, the political pressures and production costs differentials reduction, there should be an underlying factor that is helping companies to Reshore, at least in setting up manufacturing in US, instead low-cost labour countries, not only manufacturing but services either.

The answer lies in the technology, emerging technologies like Additive Manufacturing, Automation (Robotics) and Artificial Intelligence are acting as a catalyst in reshoring phenomenon.

Now, Additive manufacturing is widely regarded as the future of the manufacturing industry and is expected to transform the way in which a whole range of products are created.

Technology leaders, including Ford, Nike, GE and NASA, are rapidly adopting 3D printing within their product development structures. Wohlers Report, one of the highest regarded and most comprehensive annual reports covering the 3D printing industry, revealed in their 2014 report, "the market for 3D printing, consisting of all products and services worldwide, grew to $3.07 billion last year". This growth, according to Wohlers, is the highest in 17 years. According to a 2014 survey carried out by PricewaterhouseCoopers —an international services network for professionals—67% of the 100 industrial manufacturers surveyed are using 3D printing in some way, with 25% stating they plan to implement 3D printing in the near future. GE in particular is leading the way in taking full advantage of the benefits offered by 3D printing and North American manufacturing, and, with revenues over $140 billion, their market approach is closely followed.

In the 2012 article, "The Insourcing Boom", The Atlantic interviewed GE on their then recent reshoring plans: "…the unchallenged logic of the global economy was that you couldn't manufacture much besides a fast food hamburger in the US. Now, the CEO of America's leading industrial manufacturing company says it's not Appliance Park [the GE appliance manufacturing plant in the US] that's obsolete – it's offshoring that is.

Around 2009, GE began reshoring their appliance division back from offshore production facilities to GE's Appliance Park production facilities in the U.S., re-joining GE's energy and aviation plants scattered stateside. GE's appliance division was sold this year to Electrolux, a Swedish company. Notably, Electrolux has confirmed Appliance Park headquarters will remain unchanged, indicating their shared confidence in a technology-driven America able to remain competitive in a global manufacturing environment. The mass adoption of 3D printing is one of many factors comprising current industrial manufacturing evolutions, which cannot be separated from the greater conversation of manufacturing; globally, 3D printing is cementing itself into industrial production cycles.

A study by UNI-MORE CLUB shows 8 participants conveyed 3D printing as their motivation behind reshoring, the number might look low, but if we look closely most of the other motivations are offered by adopting Additive

Manufacturing, for example adopting additive manufacturing in home country can leads to reduction in logistics costs.

#	Reshoring motivation	No. of decisions
1	Logistics costs	136
2	"Made in effect"	124
3	Offshored production poor quality	122
4	Labor costs differentials' reduction	103
5	Total cost of ownership	101
6	Increasing service level	97
7	Lead time	82
8	Government aids	69
9	R&D vicinity to production	68
10	Firm's global reorganization	68
11	Coordination costs foreign units	63
12	Minimum size lot	40
13	Host country HR inadequacy	33
14	Global economic crisis	29
15	Organizational flexibility	28
16	Walmart incentives (only for US firms)	26
17	Emotional elements (e.g. patriotism)	17
18	Trade mark counterfeiting	16
19	Availability of production capacity at home	15
20	Host market low attractiveness	15
21	Social pressure at home country (e.g. unions)	12
22	IP issues	12
23	Duties for re-import	10
24	Process automation/New production technologies	9
25	Energy costs	8
26	***Adoption of 3D technologies***	***8***
27	Absence of suppliers in the host country	6
28	Eco-sustainability	3

Table 3:Motivations for Reshoring, data from UNI-CLUB MORE research

From Presidents to CEO's, there is a growing consensus on the way it impacts manufacturing.

"A once-shuttered warehouse is now a state-of-the art lab where NEW WORKERS are mastering the 3D printing that as the potential to revolutionize the way we make almost everything," words by Obama acknowledging the impacts of 3D printing on Manufacturing while launching the National Additive Manufacturing Innovation Institute in Ohio, 2013. This statement by president

Obama, unveils the strategy of Governments to attract companies to establish manufacturing plants not only by providing incentives alone but also supporting them technology that outweighs the low-cost production in emerging countries.

Fender Musical Instruments previously outsourced 3D prototyping. While the company saw benefits, changing to in-house prototyping with 3D printing allows the company to produce a design overnight, instead of the former two-week wait.

American manufacturers are bringing production back to the U.S. Reshoring or "nearshoring" are becoming a less expensive choice. Increases in 3D printing capabilities will allow for more manufacturing stateside at lower costs than production overseas. By the adoption of 3D printing technology smaller manufacturing plants can be developed, and plants can be located near the end user of the product.

6 TOP RESHORING CASES IN THE U.S.

Company	Total Jobs	Reshored From	State	Product Reshored
Walmart	2514	Various	TN	Various
GM	1800	Mexico	TX	Small gas engine (ecotec), SRX
Flextronics (Apple)	1700		GA	Mac Pro
Caterpillar	1400	Japan	OH	Construction equipment
Ford	1400	Mexico	MI	F-650, F-750
Ford	1400	Mexico	KY	Ford Fusion
GE	1300	China	TX	Appliances, H2O heaters
Farouk Systems	1200	China,Korea, Republic of China	GA	Ceramic hairstyling irons
NCR	870	Brazil,China, India,Hungary	MO	ATMs, self-service checkouts
Boeing	700		OH	Parts for the 777X

Source: Reshoring Initiative Library, March 2014.

Figure 11 Top reshoring cases in The U.S.

4.3. Case studies

4.3.1. Under Armour

"We're starting in Baltimore, That's our home." **Kevin Haley**, Under Armour company's head of innovation, recently told the Baltimore Sun

newspaper. Under Armour is an American Company that Manufactures footwear, sports and casual apparel, headquartered in Baltimore, Maryland U.S.

All though it serves worldwide, like other companies Under Armour so far relied on 14 low cost countries with 65% of its total products made in China, Jordan, Vietnam or Indonesia.

On June 28, 2016, Under Armour opened the UA Light House, a new centre for Manufacturing and Innovation. This is a 35,000-square foot facility which is in south Baltimore's city garage.

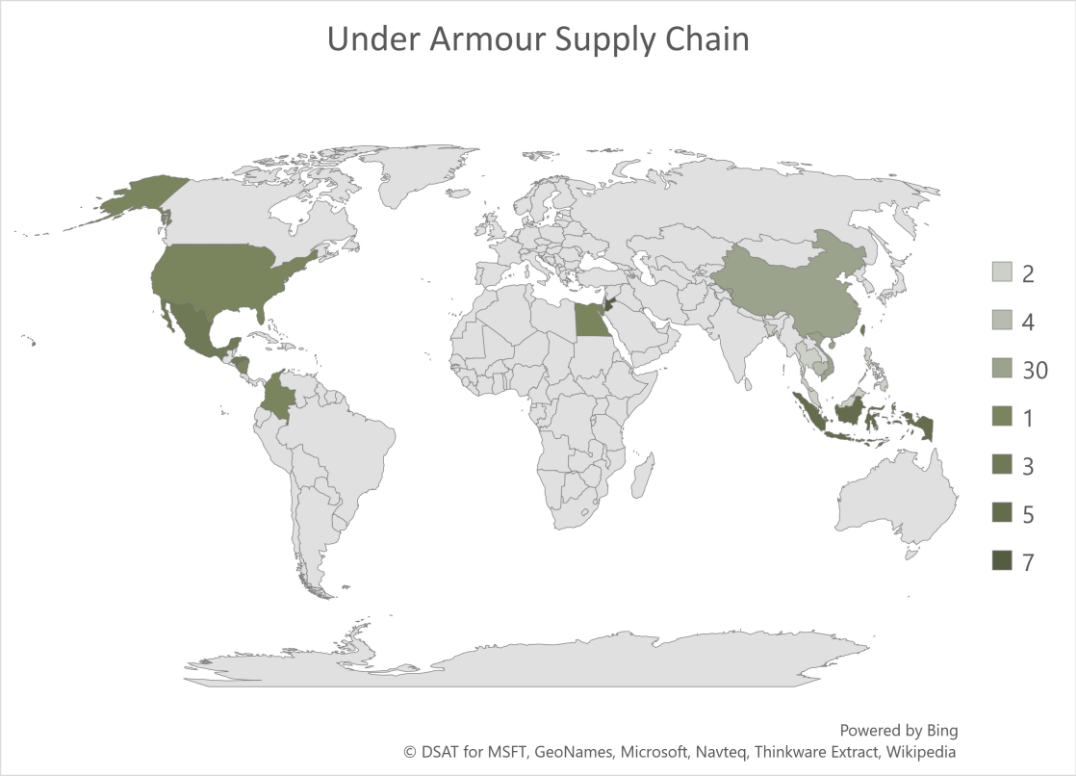


Figure 12: Under Armour supply chain http://investor.underarmour.com

"The Lighthouse is bringing our vision: Under Armour manufacturing that makes products the likes of which consumers have never seen before, designed for – and **made in –local communities in the U.S. and around the world**. If Under Armour can be more efficient, we can be more effective – and more sustainable. That's why we built the Under-Armour Lighthouse, a 35,000-sq. ft., state-of the-art advanced manufacturing and product innovation centre for footwear and apparel. The technology we bring to the Lighthouse is nothing short of the absolute pinnacle. Among its array of **capabilities are 3D design, rapid prototyping, and 3D printing**"- Under Armour to its Investors.

Now the technology is adopted to manufacture Speedform running shoes and the headcount required to manufacture decreased drastically from 150 to 30. And

Under Armour has plans to expand the additive technology to produce other products either.

But at the same time, it is worth noticing that Under Armour does not ended its relationship with Low-cost suppliers, instead it is following Local-to-Local Manufacturing strategy with the help of 3D printers.

4.3.2. Nike

Nike, a Billion-dollar American Multinational Company which has been incorporated in design and manufacturing of sports footwear and apparel.

More than 90% of total Nike foot ware products are being made by contract suppliers in China, Vietnam, Indonesia and Thailand allowing them to focus on design development and low-cost manufacturing. Nike's U.S. workers make only a tiny percent of Nike's products. In fact, Americans made only 1 percent of the products that generated Nike's $27.8 billion revenue.

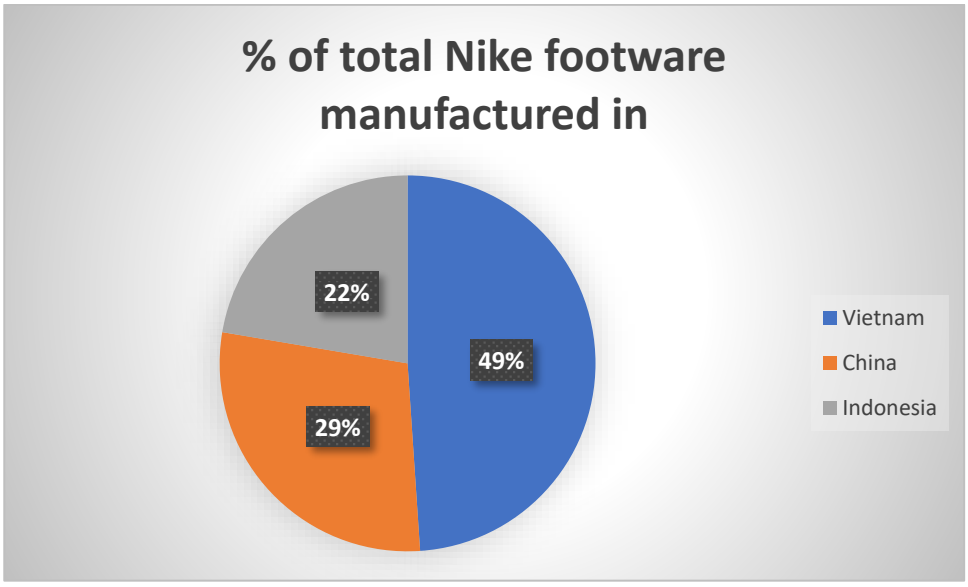


Figure 13:Nike Manufacturing

In collaboration with Multinational Informational Technology giant HP, Nike is manufacturing shoes made from 3D printer. It envisions the future of printing shoes at customers door step or at their stores by selling the IP file, reducing its reliance on its suppliers and reduction in long global value chain.

Eric Sprunk, Nike's COO, recently attended a summit held by tech news site GeekWire "You could head to Nike's website, customize a sneaker to your

specifications, and buy a file containing the instructions for the 3D printer. If you have a printer at home, you could print it yourself and have a new pair of sneakers in a matter of hours. If you don't, you could take the file to a Nike store and have them print it for you".

4.3.3. Avio Aero

Head Quartered in Rivalta di Torino, Turin, Italy, Avio Aero S.p.A is an Italian company operating in aerospace sector, which was founded in 1908 that provides automation systems, combustion technology, mechanical transmission systems, and low-pressure turbines for military and civil aircraft. Avio Aero operates Italian plants in Turin, Pomigliano d'Arco (Naples), and Brindisi, with 4,000 of its 4,700 employees in Italy. Avio Aero also has plants in Poland, Brazil, and China. Avio Aero has been a strategic supplier to GE for almost 30 years. In 2013, GE acquired aviation business of Avio Aero S.p.A for $4.3billion. The company was renamed as Avio Aero, a GE Aviation Business.

Figure 14 Avio Aero AM plant

Utilizing the additive manufacturing technology, Avio Aero set up an industrial plant in the heart of Piedmont region, Cameri, to manufacture aero engine components. Spreading over of 2,400 Sq. meter, this advanced plant accommodating up to 60 machines, this is considered as the largest factory in the world for additive manufacturing for industrial scale. This plant uses two main technologies 1) Electronic Beam Melting(EBM) 2) Direct Metal Laser Sintering(DMLS). Avio Aero has spent over $20million in additive

manufacturing technology. They considered Additive Manufacturing as one of their pillars for competitive advantage.

Figure 15 Four pillars of Avio Aero

At a dinner for Silicon Valley big shots in February 2011, President Obama asked Steve Jobs what it would take to manufacture the iPhone in the United States. Apple's founder and CEO is said to have responded directly: "Those jobs aren't coming back." But now Apple too considered manufacturing some of its Macs in US-MIT Technology Review, 2013.

In sum, it is evident that from the above three case studies, that in the near future low cost labour, which has been considered as one of the most important locational advantages of emerging countries may not be advantageous any more.

It is worth to notice that none of the companies closed their relationship with their suppliers nor closed their plants in emerging counties, but instead investing more in low-cost countries they are investing in their home country or near to the market. So, it is expected that there will be a shift from labour based economy to knowledge, technology and market based economy. So, it may not be the concept if Reshoring totally, but near shoring or market shoring. A report by Keystone Group on Reshoring Unveils an interesting fact that 25% of Executives planned to relocate manufacturing to other locations abroad, but it emphasizes these locations will be near to Market.

4.4. How does additive manufacturing affect Global value chain?

3D printing is considered as the revolutionary technology that can change the way production is organized across time and space with important redistributive effects on geography and the size of the production activities. Information and communication technology (ICT) in the second half of the 20th century facilitated the global outsourcing and off shoring of manufacturing activities, and the organization of economic activity in Global Value Chains (GVCs) – chains of activities from extraction, to processing and consumption, that are dispersed globally but centrally governed by 'lead firms' (Gereffi 1994).

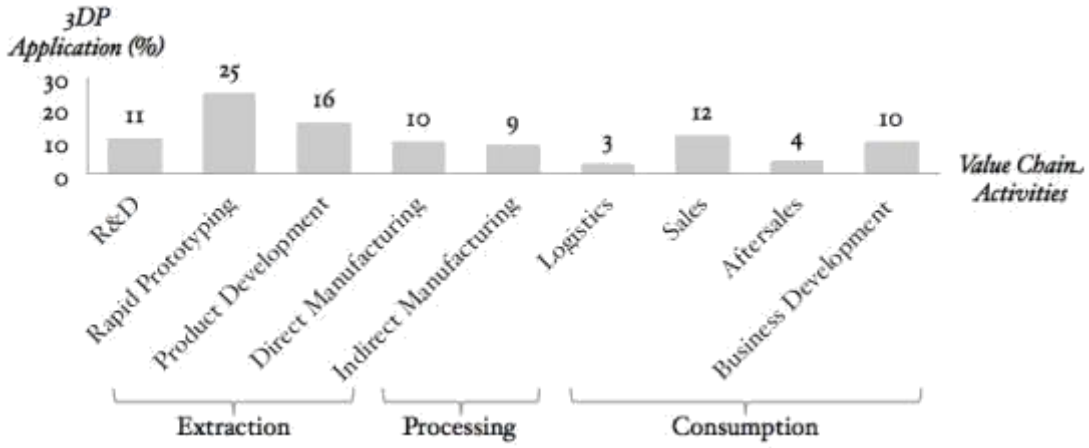


Figure 16 GVC pillars

According to study conducted by Gartner it is understood that the most activities done by the adoption of 3DP mainly focus on the extraction pillar along the value chain. The firms are seeking for the new product innovations, new designs and the innovation of the product development process through R&D, Rapid prototyping, product development, direct manufacturing and indirect manufacturing in the extraction pillar. The adoption of 3DP along the other extraction pillars has been minimal but more and more growth has been seen in the sales and the business development field in the value chain.

As you can see in the above figure most of the leading firms now adopt 3DP the most for prototyping the new products which has been a trend in the recent past but are also trying to focus in the other fields of the extraction pillar. Below we tried to explain the fields along the value chain that has adopted the 3DP technology the most.

4.4.1. R&D

The emergence of the additive manufacturing has given the possibility for development of the never before seen designs through the R&D process. The firms have been investing heavily in the development of the next disruptive technology or design in their respective industry. The firms have reluctant to leave their outdated way of thinking of the design in the past, but this thinking has been changing with the entry of new players into the industries. This competition is forcing the companies to think out of their outdated mindset regarding the design. This has been mainly with the adoption of the 3DP by the smaller firms to create the new designs with the new paradigm "Freedom of design" the trend which the leading firms are adopting as well. 3DP in R&D is clearly about product upgrading i.e. "moving into more sophisticated product lines" (Humphrey and Schmitz, 2002).

There has been a continuing growth of the 3D technology adoption in all the sectors but what made us curious is the adoption of this technology in the medical industry. The technology is allowing to the medical industry to print the parts and devices that would not been possible with the traditional technology that they have been using. Recently FDA has issued new guidelines to help advise device manufacturers on technical aspects of 3D printing that clarifies what the FDA recommends manufacturers include on submissions for 3D-printed medical devices this shows that the medical industry is moving fast with the adoption of additive manufacturing. This adoption of the additive manufacturing in R&D of the medical sector would be a potentially game changing in terms of treating the people with disabilities and emergencies caused by various factors not only to the humans but also to the animals.

4.4.2. Case study Clariant

Clariant company which is specialised in chemicals is planning to lunch a business for premium and customised 3D printing filaments. Clariant state that its new business leverages the company's experience in tailoring polymers for end market applications with pigments, additives and masterbatches, to provide high-grade, 3D printer filaments and specially made solutions.

Clariant are planning to invest in the R&D of the additive manufacturing which would allow them to enter into the business of filaments. They strongly believe the company's experience in tailoring polymers would be enough to launch into the new business sectors.

Adoption of the additive manufacturing is making it easy for the company to look beyond their section of value chain. This would be the trend for the future as many companies will be opting to enter into the new markets and explore the opportunities of investments made possible with the adoption of additive manufacturing.

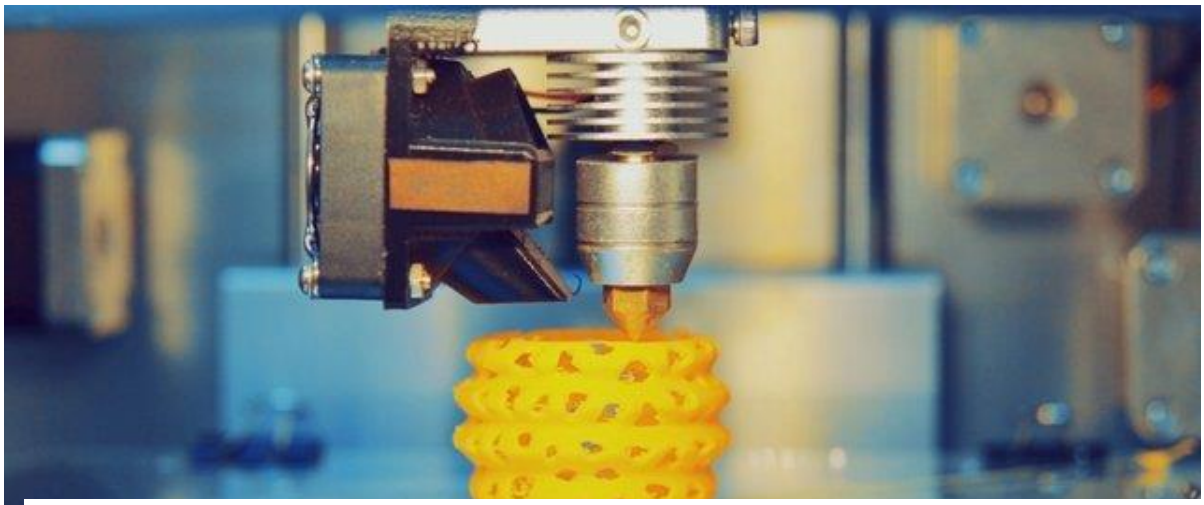


Figure 17 Clariant 3D printed filament

Figure 18 AM growth in R&D
source: MPN

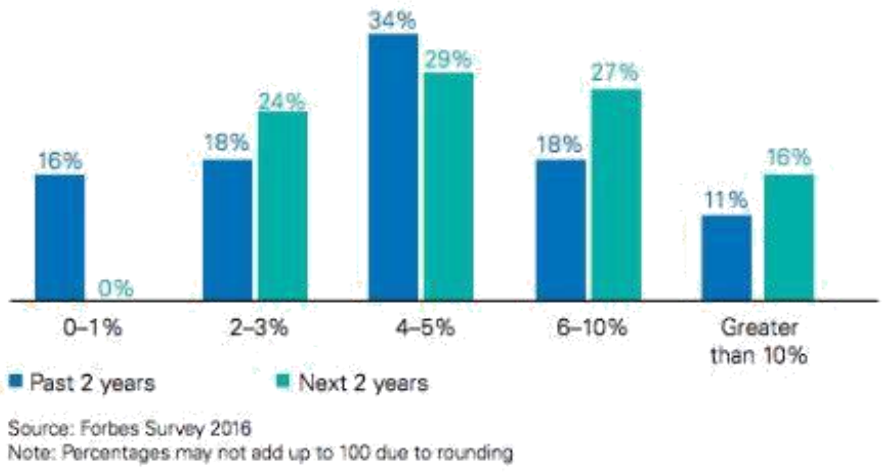


Figure 19 AM growth in R&D

4.4.3. Rapid prototyping

Rapid prototyping is definitely the technology that has been changing the way how the companies and the commercial entities doing business. In my opinion as well as the many others this technology must be the most exciting and also emerging technology in the last couple of years that has gained and expected to gain even more momentum in the years to come. The applications and also the uses of this technology will allow the companies to best practice in prototyping phase of the global value chain.

4.4.4. Case of McLaren

Steps towards additive manufacturing in GVC. Recently McLaren automotive company has agreed to partner with Stratasys a specialised 3D printing company to allow them to supply them with the 3D printing and additive manufacturing solutions. Under this agreement the Stratasys will supply the McLaren with its latest FDM and polyjet based 3D printing solutions and cutting-edge materials for visual and functional prototyping, production tooling including the composite tooling, and customised production parts.

This introduction of the additive manufacturing in the prototyping phase of the global supply chain will allow them to speed up the process and also give them the opportunity to explore and utilise all the dynamic designs at were not possible by the traditional prototyping that is being followed by the company presently and also cut the time to the market increasing also the output of the company.

"The ability to rapidly model, build and evaluate new components is an invaluable asset for any fast moving and dynamic organization" said McLaren's racing.

Figure 20 McLaren evolution

This example shows the adoption of the Additive manufacturing has been increasing along the global value chain in the fast moving and dynamic organizations. As you can see in the pie chart below the adoption of this technology has been in rise and expected to increase even more in the other sectors as well. The graph gives an idea of the expectations that the additive manufacturing is going to create and the productivity.

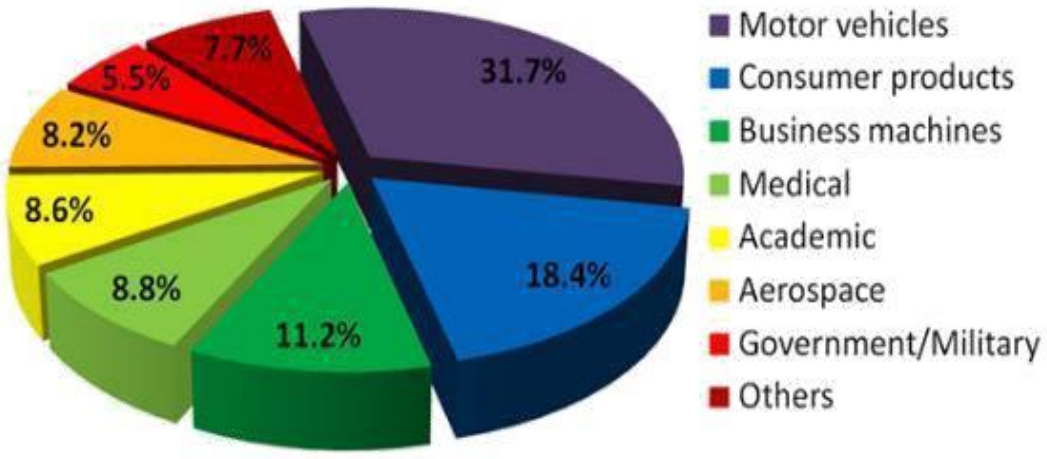


Figure 21 use of 3d printers in industries

4.4.5. Product development & processing

The main purpose behind the adoption of 3DP technology in the product development phase is both about the product and as well as the process upgrading. 3DP can be used to improve the properties in the products that already exist in the portfolio of the firms and also in the process of transforming the inputs more efficiently into the final outputs. The adoption of 3DP can help save almost 90% of the material waste that the companies have today with the traditional manufacturing methods. Nonetheless, the main thing to consider is the cost of raw materials of 3DP which is higher than the traditional manufacturing raw materials. In sustainability point of view material savings is a very interesting for the firms in the future. But the studies show drop in the percentage of 3DP adoption in accelerating the product development in future as the companies considering adopting the technology into other fields of the process in the value chain

4.4.6. Case of Ferrari

Ferrari considering 3-D printing for advanced piston design

In its bid to optimize engine design, and more specifically in the combustion chamber area, Ferrari's engineers are considering using Additive Manufacturing technology that involves adding layer-upon-layer of material, whether the material is plastic, metal or concrete to form a component for the Ferrari cars that will be manufactured for the racing purpose and soon could be used in the commercial engines that the company will develop in the future.

Ferrari's 2017 engine design is rumoured to have very little in common with its previous iteration, with engineers having specifically focused on combustion, with substantial increases in both pressure and temperature which could pose a threat to reliability. s it looks to optimize its components, both in terms of design and material, Ferrari is seeking to innovate with Maranello engineers assessing 3-D printing as a possible means to create complex forms which cannot be achieved using traditional casting and machining processes.

Figure 22 Ferrari piston pump

But the innovative technology also allows the use of steel allows instead of aluminium allows, with the former offering better resistance to pressure and temperature while no longer presenting a weight disadvantage compared to aluminium alloys, thanks to a specific honeycomb form achieved in the manufacturing process by 3-D printing. This development of the products that already exist in the company with the help of the additive manufacturing might see the change of the global value chain of Ferrari. This might allow the company to reduce the wastage of raw materials more than the traditional process the company has been following. The introduction of additive manufacturing into their global value chain would allow them to have a major advantage over its rivals and force them into adopt this technology in the near future.

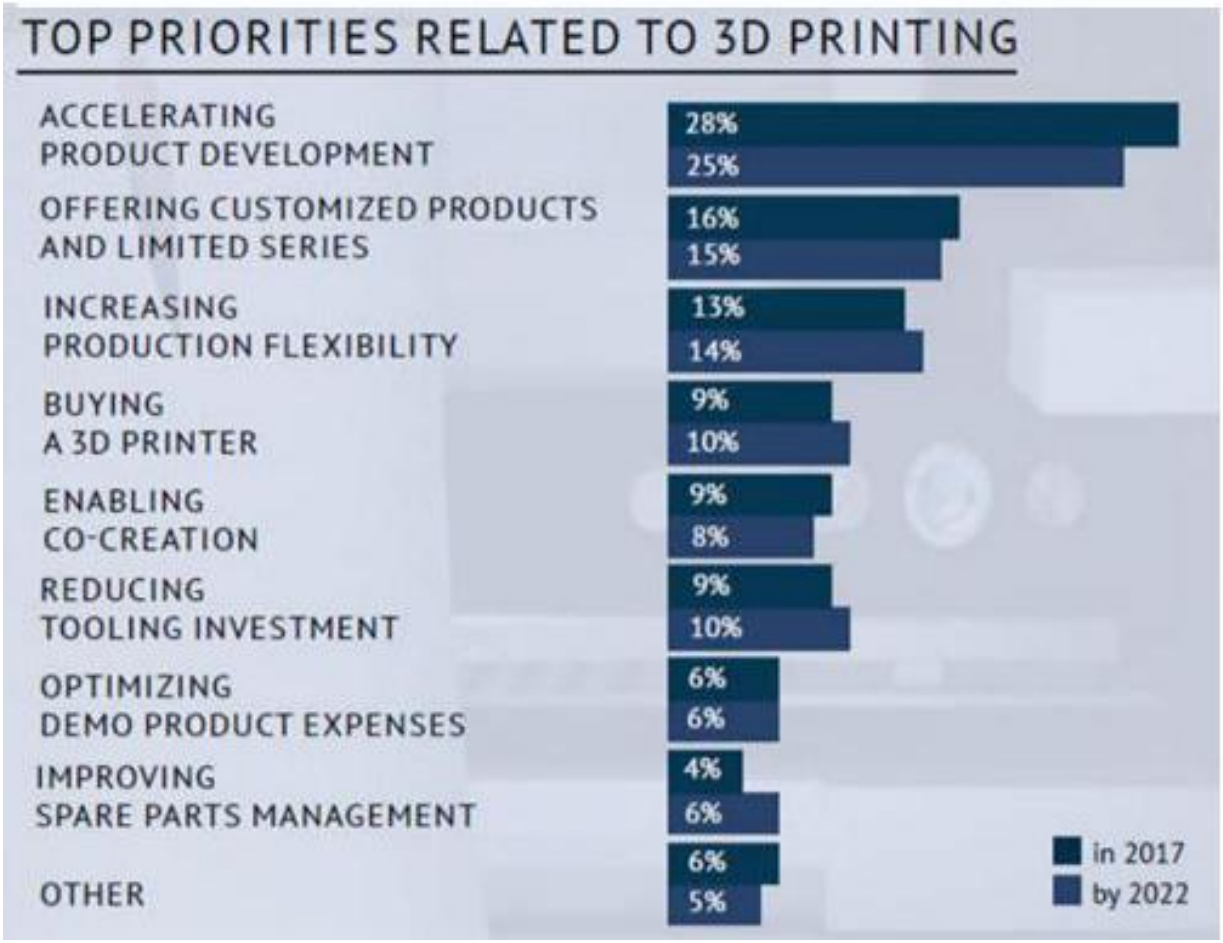


Figure 23 Top priorities related to 3DP

4.4.7. Direct manufacturing

One of the most important advantage we have with the 3DP technology is that the companies does not need economies of scale in order to return positive returns on the invested they made compared with the traditional

manufacturing because of the lower capital investment for manufacturing facilities (Khavaji et al 2014; D'Aveni 2015), as the economies of scope creates profit in case of 3DP.

In GE's case, the full volume production of the fuel nozzle will save them 75% in manufacturing costs (GE Reports 2015). In the words of David Joyce, CEO of GE Aviation, "we no longer have to understand what the limitations of the machine are or the costs of what those limitations are." (GE Aviation 2013, 1:30). The study made by Gartner reveals that if all the benefits of the 3DP in the processing stage are rightly quantified then the mean cost reduction for final goods will reduce by 4%.

4.4.8. Indirect manufacturing

An important opportunity 3DP presents is elimination, or at least the reduction of several processes in the smile curve of traditional manufacturing. The companies which adopt the 3DP technology will be able to reduce the assembly line process from several steps to very few. The actors are who are able to successfully eliminate the steps in the assembly line through 3DP are the ones that are upgrading their skill set to think of their prospect products in terms of systems rather than as sets of individual parts. Products with high transaction costs such as high asset specificities and/or intensive and specialized labour, 3DP means process upgrading and even abandoning processes traditionally needed for production (Appleyard 2015). This means the adoption of the 3DP technology in the indirect manufacturing is affecting the GVC to become leaner than before.GE managed to reduce with their fuel nozzle – printing 18 separate parts in one (Wohlers 2014).

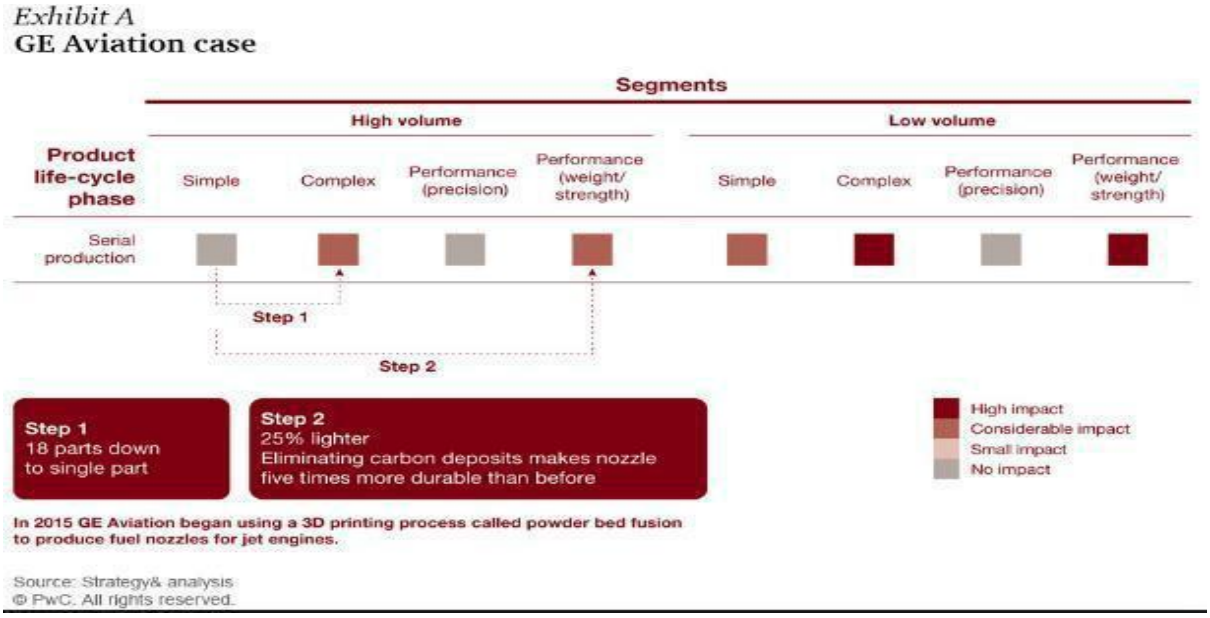


Figure 24 GE aviation

4.4.9. case study GE

GE's largest and most efficient gas turbine the HA, nicknamed HArriet, has broken its own net efficiency record. Beating previous orders at 63.7% efficiency, the HA is now available at 64% under conditions recorded at a test plant in Greenville, South Carolina. The company attributes this feat to "combustion breakthroughs through constant innovation," and applying additive manufacturing to a number of the turbine's key components.

Figure 25 Turbine with 3d printed components

The 64% efficient 9HA.02 turbine clocks a total output of 826 megawatts in a combined cycle configuration. According to GE Power estimates, the additional units of power translates into "to millions in fuel savings for customers globally.

Design of the engine's combustion system was optimized using metal 3D printing. With more complex geometries, engineers improved the premixing of fuel and air in the turbine to achieve maximized productivity.

Additive manufacturing has also been rolled out in the development of GE's next generation helicopter and business jet engines, affirming a commitment to its success.

The other fields along the global value chain which see the changes due to the adoption of 3DP technology is logistics, sales & after sales, business development. In case logistics, this vision implies a decrease in transportation costs, inventory and warehousing costs, and shorter lead times across supply chains (Khajavi 2014)

In global logistics as we can see if the international logistics cost increases the more and more the 3D printing technology will be affordable. The manufacturers may think of shifting their manufacturing facilities to their own country which means if the manufacturing of products or components in the foreign soil reduces the use of the air and ocean freight quantity will reduce drastically reducing the demand of the brokers that are involved in the international logistics.

One of the main value additive manufacturing may bring is creating a customer specific complex items that can be made only when the order is made by the customers. This would mean the companies do not need to have the inventory in their warehouses in order to deliver it to the customers as it takes only a couple of hours to print the product for the customers. Hence the need for the high-volume production and the reliance on the workers will reduce significantly and a part of supply chain will become superfluous.

One of the most important challenge every global value chain faces is the reduction transportation costs as the manufacturing facilities are located in the foreign locations. The adoption of 3D printers means the companies can locate close to the end users or strategic markets which will help them to reduce the transportation costs involved. It will shorten the supply chain and also reduce the impact on the environment. Local 3D manufacturing centres will allow the shippers to deliver faster without any delay due to the transportation failures or bad weather.

Additive manufacturing will change the relationship between the customers and the companies. It will change how the customers will relate to the companies by reducing the mediators in between them. The future trends with see the customers owning the 3D printers at home which will allow the companies will sell their product design online and the customers can print them at home. Such changes will help meet the customers demand and also reduce the cost of doing business.

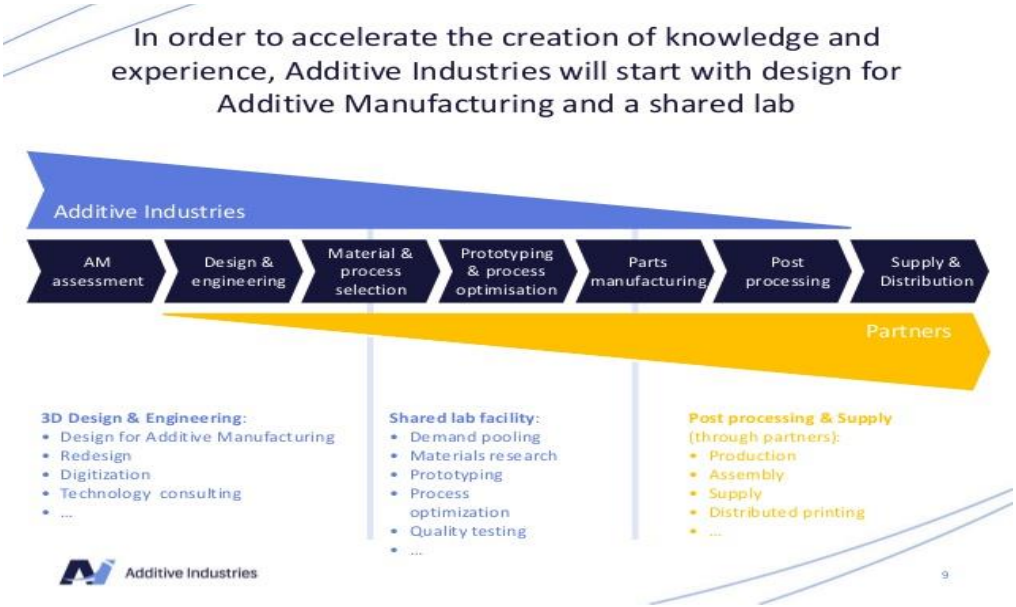


Figure 26 AM innovation in supply chain

4.4.10. 3D printing for mass production

As the speed increases and the cost comes down, manufacturers who used to rely on machining and injection molding will turn to 3D printing, and those with a lower production volume are likely to make the switch first. Where companies currently use machining for a few thousand parts, the material is restricted to metal. By turning to 3D printing, plastics become an option.

With increased production, the cost of those plastics will come way down as well, making the whole technology easier on the budget. It's only because 3D printing remains a niche means of production that the cost of materials is so high. The same materials cost much less when slated for injection molding, but only because of the size of the market. As 3D technology speeds up and spreads out, materials companies are likely to drop the costs as they rise to meet the demand. Many injection molding companies know that the 3D printing is going to take the bite out of their business and are trying to adopt to this new technology and invest in them. But additive manufacturing has a much narrow range of materials available to it

4.4.11. IKEA

First to adopt 3D printing for mass production. IKEA is introducing its first mass produced 3D printed home objects. It is One of the first movers to adopt additive manufacturing technologies for mass production. IKEA announced that it will be releasing the unique OMEDELBAR collection next year, in collaboration with

stylist Bea Åkerlund. Jakub Pawlak, with Trader Free Range IKEA Poland, is in charge of the ground-breaking project. The OMEDELBAR collection features a mesh-inspired design of a stylistic, deconstructed human hand. The 3D printed hand looks like it's reaching out for something, and can be used as a decorative jewellery holder or a piece of unique wall art.

Figure 27 3D printed hands by Ikea

Ikea believe they are closing fast on the breaking point where 3D printing is cost efficient in mass production. IKEA will probably not stop there in regard to 3D printing. Whether for its hacks or small decorative objects, the Swedish company is convinced that technology can bring a lot to the table. It believes in the potential of 3D printing on demand and sees it as a solution to lower production costs.

We tried to explain scenarios how the global value chain smile curve would change by the adoption of 3D printing based on the figure above. The adoption of 3D technology as a complement for the existing process would mean that the extraction and the consumption pillar would move closer to the processing pillar as you can see in the figure. This would make the smile curve even more smirking. In other case i.e., 3D technology as a substitute mean the global value chain smile curve will move upwards.

4.4.12. Future trends of 3D printing technology

A trend that is on the rise is starting to get a lot of interest due to its high potential. Most of the time, no usable product exists, only proofs of concept or relevant

research. These definitely are the trends to watch in the coming months and years, due to how they could drastically change things regarding 3D printing. A trend that is at this peak is at the moment when expectations regarding it are the highest. There already are some success stories with it. But it's not commonly adopted yet.

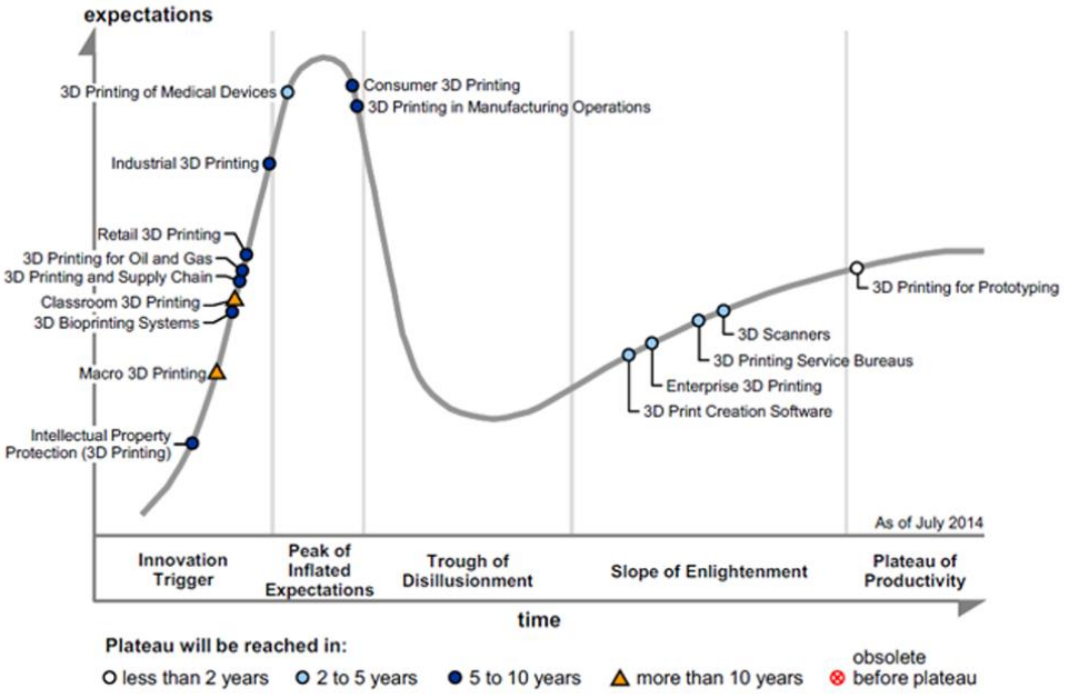
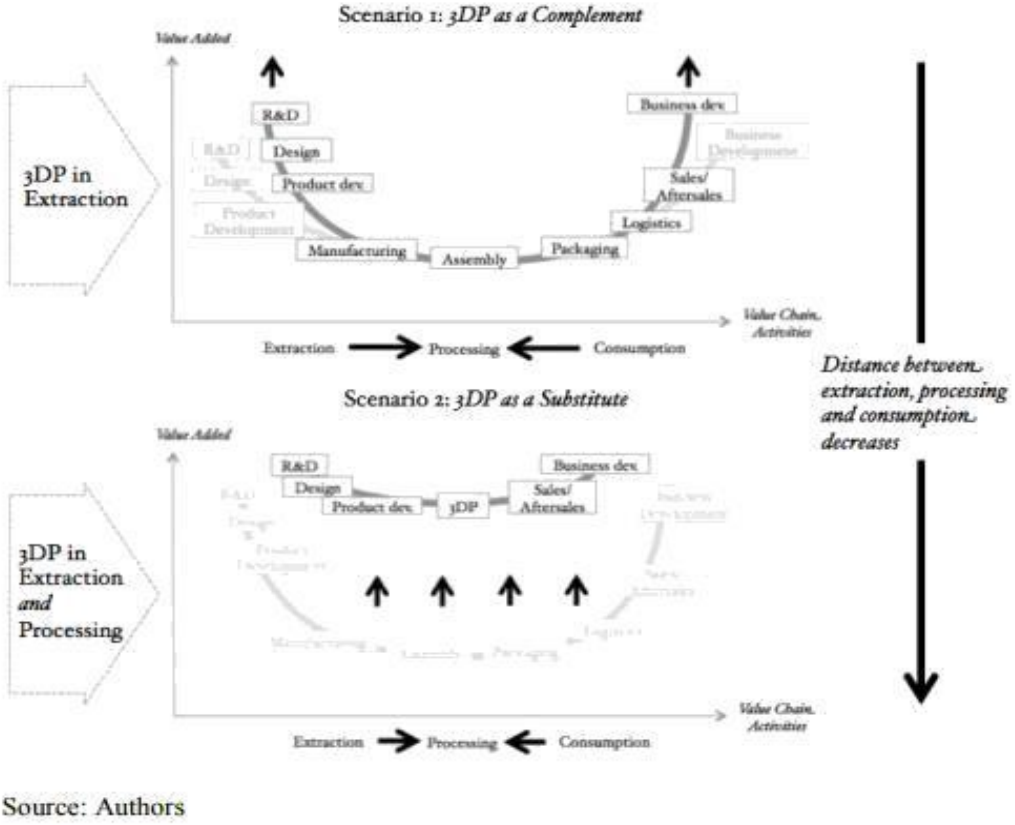


Figure 28 Gartner Hype curve of 3D printing

The step sliding into through corresponds to the moment where there is a wave of disillusion about a 3D printing trend. Most of the time, experiments and implementations fail, and people tend to think that the high potential that was seen can't actually become a true reality. But most of the time, it's only momentary.

Trends that are climbing the slope of enlightenment start to be more widely understood and used. Second and third generation products start to appear on the market, being more performant and satisfying for the customers. Conservative companies remain cautious though. Finally, a trend that is entering the plateau of productivity is at a moment where it starts becoming mainstream and widely adopted.



Source: Authors

Figure 29 3DP scenarios for GVC restructuring

We tried to explain scenarios how the global value chain smile curve would change by the adoption of 3D printing based on the figure above.

In the first scenario, 3DP is applied for rapid prototyping in the extraction pillar, or for the production of specialized machine tooling in the processing pillar. 3DP is applied to decrease development cycles of products that are subsequently mass produced using traditional technology and infrastructure. This implies a new level of control and coordination, by means of re-bundling activities. Furthermore, such control is not primarily driven by product quality or quantity, but by control over time and space to respond to consumer demands – by supplying the right customized product at the lowest possible lead-time.

The second scenario is a GVC of mostly or fully 3D-printed products, where the replacement of 3DP in many manufacturing industries removes low-skill, labor intensive and low-value added functions in the processing pillar. In this substitution scenario, automation pushes the smiling curve upwards, and production becomes decentralized and moves away from where it had been previously outsourced, to be located near the end-consumer. 3DP would reduce

the need for assembly, packaging and transport, and thus decrease the number of nodes in the ideal GVC altogether – through a process of ‘rebundling’. Production becomes even more on-demand than in the first scenario, and control over time and space even further enhanced.

5.Conclusion

As Additive Manufacturing has been innovating, especially in this decade, everyone is interested in its capabilities and engineering perspectives. Very few worked on the Business perspective of Additive Manufacturing and we are happy that we are one among them.

The data available, it may be either qualitative data or quantitative data, is very minute and scattered, we relied on secondary data. And tried to compare and relate different works and actions by companies.

In Literature review we discussed advantages and disadvantages of additive manufacturing, we carried out this at three levels of a company i.e., production level, company level and market level. And then we analyzed its impacts on some important areas of International Business. Then we focused our attention on two important aspects by questioning ourselves the following two questions and then we tried to answer them by exploration

1) *Does Additive Manufacturing is affecting the locational advantages of Low cost emerging countries? Could Additive Manufacturing encourage Reshoring?*
2) *Does Additive Manufacturing affect the Global Value Chain(GVC)?*

In answering the first question, we discussed the concept of offshoring and the factors that compelled companies to offshore their production and made a pest analysis for low cost countries. Then we discussed the growing consensus among the economies on the importance of reshoring i.e., bring back production. For this we stated some of the statements of Obama and Trump and some examples of companies that Reshore. Followed by, our work focused on Importance of additive manufacturing on Emerging countries advantages and have written three case studies and analysed. Upon this work, we state that even though still the waged in advanced countries are higher when compared to emerging countries, Additive manufacturing is acting as a catalyst in helping companies to bring back their production which is coupled to other factors like political pressures. Also we predict that there is and will be a transition from labour based economy to Knowledge, Technology and Market based economy.

For the second research question based on the papers and information we have gathered we tried to explain how the adoption of 3DP technologies could impact the traditional global value chain. 3DP technology is expected to revolutionize the manufacturing industries even further in the future. The adoption of 3DP technology in various stages along the global value chain is expected to change the complexity of the supply chain by reducing the number

of nodes in the assembly processes. The implication of 3DP suggests that the actors are able to acquire new capabilities that are able to restructure their GVC's. Increased control over time and space suggests that more value can be created with the adoption of 3DP.

But increasing output in the world economy has not historically translated into an equal distribution of value among GVC participants.

we used the automotive industry as a main example to see the future trends that of the adoption of the additive manufacturing. The adoption of this technologies by the top MNEs would be a major hint that the all the industries are definitely feeling the importance of it and the considering the impacts that the adoption would bring in the way of business done.

One of the most important question to be answered is to what possible extent the increase in the value added can benefit different countries and different actors as both lead firms supplying 3DP technology and lead buyers of it are currently based in advanced economies. It is clear based on the study we have done that the leading firms from developed economies are pursuing and will continue to adopt the 3DP technologies but the firms from the emerging and under developed economies has very limited access to this technology and uncertain know how that is still not clear. whether the GVC restructuring that may ensue has a transformative or a reproductive character only can be seen with time.

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