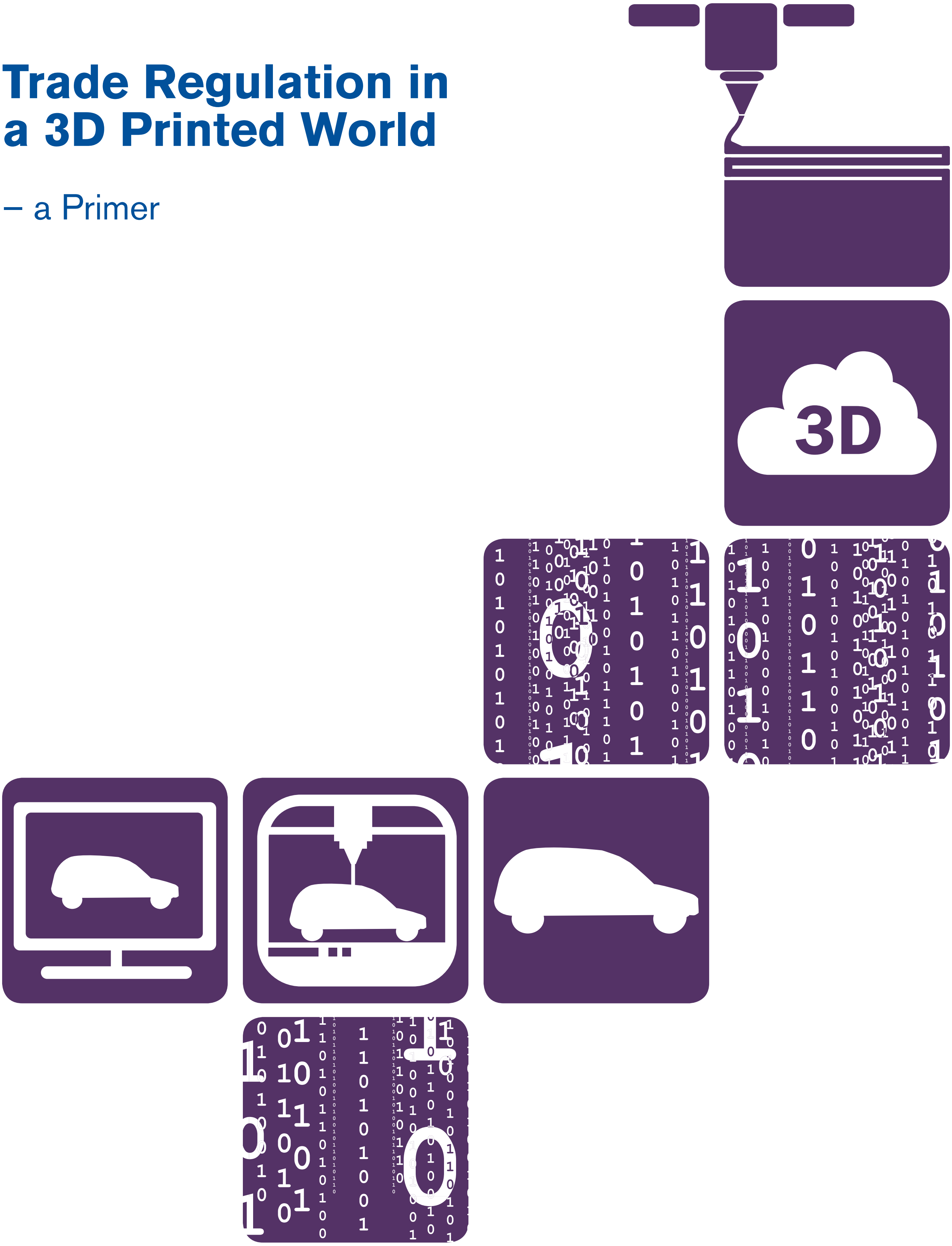
Kommerskollegium 2016:1

Trade Regulation in a 3D Printed World

– a Primer



Kommerskollegium
National Board of Trade

National Board of Trade, April 2016 – First Edition. ISBN: 978-91-88201-12-6

Foreword

3D printing is challenging the world, trade as we know it, and established trade rules. Jokingly, 3D printing has been compared to the Star Trek “replicator”, a machine that can manufacture anything needed out of pure energy. Indeed, seeing objects materialise in front of your eyes does make you wonder if science fiction is here already.

3D printing is a manifestation of how technology is changing business models, trade flows, production networks and capabilities. As 3D printing becomes more common, new business opportunities and trading possibilities will emerge. Regulation and policy have not always kept up with technological changes. This report examines whether 3D printing, and the technological development it represents, makes it necessary to upgrade existing trade rules.

This report was written by Magnus Rentzhog with the help of the following sectoral experts: Sun Biney (SPS), Jonas Hallberg (TRIMS), Maria Johem (industrial goods), Heidi Lund (TBT), Martin Magnusson (trade defence instruments), Kristina Olofsson (agriculture), Sara Sandelius (public procurement, dispute settlement), Petter Stålenheim (statistics), Anneli Wengelin (trade facilitation), Christopher Wingård (rules of origin), and Camilla Östlund (TRIPS, dispute settlement).

The National Board of Trade would like to thank Martina F. Ferracane (ECIPE) for valuable comments.

Stockholm, April 2016

Anna Stellinger
General Director
National Board of Trade

Executive Summary

3D printing (3DP) is a technology that builds physical objects directly from 3D computer-aided design (CAD) data and adds different materials, layer-by-layer, with the help of a 3D printer. With 3DP certain stages of manufacturing are bundled into one and certain transportation of goods is replaced by transmission of data.

In 3DP, the creation and transfer of the CAD-file is the essential component and the main difference between 3DP and traditional manufacturing. The main features are almost no economies of scale and complexity is almost cost-free. The cost-advantage of manufacturing large quantities is removed and allows for profitable printing of smaller numbers. Additionally, the cost-disadvantage of making complex goods is reduced as 3DP makes it almost as easy to design complex items as it is simple ones. These features allow for moving manufacturing (printing) closer to the consumer (near-shoring) and for more adaption to the individual's needs. 3DP is becoming increasingly used in a number of sectors.

Two questions arise:

1. How does the spread of 3DP change how companies trade and what they trade?
2. Is WTO equipped to regulate production using 3D technology and trade with 3D-printed products?

3DP is changing trade and production flows. It also changes who participates in trade and production. It changes the production process by removing the need for intermediary goods beyond the "ink" and by allowing manufacturing to be spread out and moved closer to consumers. Intermediary goods are replace by CAD-files, hereby adding a central digital input (a service) to the process. In sum, production chains are made shorter.

3DP allows for new companies, often SMEs or private individuals, to enter the supply chain and participate in production. This includes designers of CAD-files and companies running platforms where these files are created and traded as well as new producers (that start producing goods even on a small scale for niche markets). Different types of firms are emerging, such as print shops and so-called FabLabs, where customers can have items developed and printed. On the input side, new "ink" producers are emerging – even though traditional manufacturers are set to dominate this part of the production chain.

This 21st century type of production and trade is governed on the multilateral level by the WTO, with its rules developed for 20th century based trade. Still, these rules generally work well. There are several reasons behind this finding, including the fact that many WTO rules are flexible and technologically neutral. There is no need for major legal changes due to emergence of 3DP.

Nevertheless, three challenges can be identified.

First of all, the fact that 3DP more easily moves manufacturing to the same location as the consumption means that some WTO agreements are not applicable, as there is no cross-border trade in goods.

Second, 3DP means that one set of rules becomes more relevant at the expense of another: from goods-related agreements, to services-related agreements. This is due to the creation of CAD-files, which are a central feature of 3DP. This digital task removes the need for intermediary goods and goods-related activities are replaced by services. However, how much of the production chain that will fall under GATS (WTO's services agreement) is unclear, not the least depending upon the interpretation of the borderline between what is a good and a service according to WTO-legislation. Alternatively, the introduction of the services tasks leads to a situation where there is a change of focus within a specific agreement.

Third, there are some instances where WTO rules may need to be revisited and updated or clarified:

- 3D printed products might not be "like" products allowing for differential treatment.
- Insufficient rules on export restrictions opens the door for curbing exports of raw material and "ink".
- The central task of transferring data is not explicitly covered by GATS, opening up the possibility of barriers on digital transfers.
- Intellectual property rights are essential but can be hard to apply and differences between different countries create uncertainties.
- GATS lacks rules on a number of issues making WTO Members less bound by trade regulation.

As pointed out in the last point, a consequence of the move towards GATS is less legal security. This has to do with the fact that the GATS lacks some rules that are found in goods-related regulation. Hence, a company that switches to 3DP is actually moving into less regulated territory.

Finally, since 3DP changes how production takes place, where manufacturing is done, and who participates in trade and production, it should also change trade negotiations. These changes should be taken into account in policy making.

Sammanfattning på svenska

3D-printning (3DP) är en tillverkningsmetod där föremål skapas med hjälp av olika material, lager för lager, i en 3D-printer. Printern styrs med hjälp av programvara, s.k. 3D Computer-aided Design (CAD) data. Vid 3D-printning minskar antal steg i tillverkningsprocessen till ett genom att flera steg slås ihop till ett. Dessutom ersätts viss transport av insatsvaror av överföringar av digital information, dvs. data.

Vid 3D-printning är skapandet och överförandet av CAD-filen den centrala komponenten i tillverkningsprocessen. Den är även den största skillnaden mellan 3DP och traditionella tillverkningsmetoder. De främsta egenskaperna som 3DP medför är en, i princip, borttagande av skalfördelar och att en ökad produktkomplexitet i stort sätt inte medför några högre tillverkningskostnader. Härmed minskas de ekonomiska fördelarna med masstillverkning och tillåter lönsam tillverkning av även mindre volymer. Samtidigt försvinner problematiken med att det är dyrare att producera mer komplexa varor. Det blir i stort sett lika dyrt att skapa enkla som komplexa produkter. Tillverkningen (själva printningen) kan därmed flyttas närmare kunderna (s.k. ”near-shoring”) och öka anpassning till olika kunders individuella behov och krav. 3DP används alltmer i olika sektorer.

Tittar man på 3DP utifrån ett handelsperspektiv så uppstår två frågor:

1. Ändrar 3DP hur företagen handlar med varandra och vad de handlar med?
2. Är Världshandelsorganisationens (WTO) regelverk rustat att hantera 3D-baserad produktion och handel med 3D-tillverkade varor?

3DP förändrar handels- och tillverkningsflöden. Tekniken möjliggör även för nya aktörer att delta i handeln och produktionen. 3DP ändrar dessutom produktionsprocessen då inga andra insatsvaror än materialet som ska användas i printern (”bläcket”) längre behövs. Det tillåter även att tillverkning kan flytta och spridas geografiskt, närmare kunderna. Insatsvaror ersätts av CAD-filer och en central digital insatstjänst förs in i produktionsprocessen. Produktionskedjan blir således kortare än tidigare.

Nya företag, många gånger små verksamheter och privatpersoner, får ökade möjligheter att bli en del av en varas produktionskedja och delta i tillverkningsprocessen. Detta inkluderar skapare av CAD-filer och företag som driver de molnbaserade plattformar där filerna skapas och säljs. Även nya tillverkare får möjlighet att hitta nischmarknader för småskalig försäljning. Nya former av företag har dykt upp, som t.ex. “print shops” och så kallade “FabLabs”, dit kunder kan vända sig för att få föremål skapade och printade. På importsidan dyker nya ”bläcktillverkare” upp även om traditionella råvaruförädlare troligen kommer att fortsätta dominera denna del av produktionskedjan.

WTO reglerar denna nya form av produktion och handel. Trots att WTO:s regelverk skapades för mer traditionell handel så fungerar reglerna ändå tämligen väl för 3DP. Det finns flera anledningar till detta. Grundläggande är t.ex. att många av WTO-reglerna är flexibla och neutrala när det kommer till vilken tillverkningsteknik som används. WTO behöver därmed inte genomgå någon större uppgradering för att ta hand om 3DP och de förändringar på handeln som tekniken medför.

Trots detta har vi identifierat tre utmaningar för regelverket.

1. Det faktum att 3DP gör att tillverkning relativt lätt kan flyttas till kunden medför att en del WTO-avtal inte längre är tillämpningsbara. Detta eftersom den gränsöverskridande handeln med varor försvinner.
2. 3DP innebär att visa regler blir mer relevanta på bekostnad av andra. Det sker en förskjutning från varurelaterade regler till tjänsteregelverket. Detta sker eftersom skapandet av, och handeln med, CAD-filer är en central del av 3DP. Denna digitala arbetsuppgift tar bort behovet av insatsvaror och vissa aktiviteter som är förknippade med varuhandeln ersätts av tjänster. Hur mycket av tillverkningsprocessen som kommer att falla under GATS (WTO-avtalet som reglerar tjänster) är oklart och beror mycket på WTO-rättens syn på var gränsen går mellan vad som är en vara och vad som är en tjänst. Alternativt kan ökningen av tjänster i tillverkningsprocessen innebära att vissa delar av en specifik uppsättning WTO-regler blir mer relevanta än andra.
3. Det finns situationer då WTO-regelverket trots allt kan behöva ses över, uppdateras eller förtydligas:
   - 3D-printade produkter kan betraktas att inte vara "liknande" produkter vilket möjliggör differentierad behandling.
   - Otillräckliga regler gällande exportrestriktioner öppnar dörren för begränsningar av export av råmaterial och "bläck".
   - Den centrala uppgiften i 3DP att överföra data mellan länder täcks inte uttryckligen av GATS (WTO-avtalet som reglerar tjänster), vilket kan leda till begränsningar av digital dataflöden.
   - Immaterialrättsskydd är avgörande men kan vara svår att använda och skillnader mellan länders system skapar osäkerhet.
   - GATS saknar regler för ett antal frågor kopplade till 3DP vilket gör WTO-medlemmar mindre bundna av handelsregelverket.

En konsekvens av den sista punkten (att GATS saknar en del regler som återfinns i de varurelaterade delarna av WTO-regelverket) är ökad rättsosäkerhet. Ett företag som ställer om till 3DP kommer således att befinna sig i ett mindre rättsligt reglerat territorium.

Slutligen, eftersom 3DP ändrar hur varor produceras, var tillverkningen sker och vilka som deltar i produktionen och handeln, så borde tekniken även förändra handelsförhandlingar. Dessa ändringar bör beaktas när länder tar fram sina förhandlingsmål och strategier för att uppnå dessa.

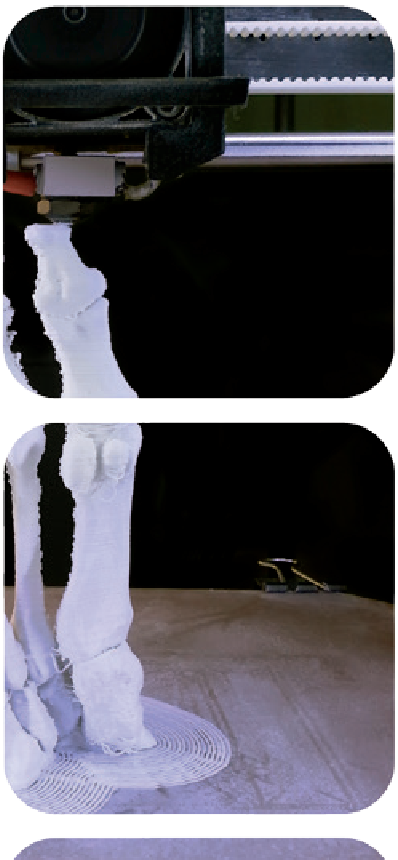
Contents

1. Introduction

> *"3D printing is a rare case where the technology is way ahead of business models, legal developments, and social and moral issues".*
>
> *Diegel (2015)*

3D printing (3DP) is spreading rapidly and is transforming traditional manufacturing and trade. The technology is developing fast and more and more companies are starting to, or at least considering how to, use the technology.[1] However, the spread of 3DP is held back by a number of factors, including technical, legal, and social obstacles and concerns. While rapid scientific advances are tackling technical restrictions[2], progress is slower when it comes to legal and social concerns. 3DP raises a number of issues, including questions relating to environmental and labour effects, safety, and legal issues (including the question of liability).[3] Legal uncertainty is a major challenge for widespread adoption of 3DP.[4]

> *3DP is a technology that builds physical objects directly from 3D computer-aided design (CAD) data and adds different materials, layer-by-layer, with the help of a 3D printer.*



A specific set of legal issues is trade regulation. Like all economic activities, 3DP takes place within the multilateral trade framework of WTO rules and regulations. Rapid expansion of 3DP, and the realisation of the potentials it holds (as presented in chapter 2), is facilitated by a legal framework that gives producers and users legal certainty. Preferably rules should be multilateral and apply equally to all countries. This has to do with the fact that production is spread out to many countries and 3DP will potentially spread the production even more (see chapter 2.2). WTO is the preferred arena for rule-making as bilateral and regional trade agreements can mean that different rules will apply to different parts of a production chain. This is the reason why this report use WTO-legislation as the basis for analysis.

With 3DP certain stages of manufacturing are bundled into one and certain transportation of goods is replaced by transmission of data. Two questions arise:

1. How does the spread of 3DP change how companies trade and what they trade?
2. Is WTO equipped to regulate production using 3DP technology and trade with 3D-printed products? Will some parts of the regulatory framework become obsolete and other parts become more important? Are there areas where a lack of WTO rules might become problematic?

This report sets out to discuss these questions. However, it does not in any way exhaust the topic and should be seen as an initial discussion – a primer.

3DP is one example of how trade and production is transforming. Just like the trend towards "servicification" of manufacturing[5], i.e. how manufacturing becomes more and more services dependent, the use of 3DP blurs the distinction between manufacturing and services. In this sense, this report could be viewed as part of a growing literature on whether WTO is fit for purpose in today's and tomorrow's trade and production environment.

The report starts with describing 3DP and presenting the technology, usage today, and where 3DP might be heading. The second part will discuss the first question posed above and discuss how this technique changes trade and production patterns and participation. Thereafter the relevance of current WTO regulation is examined. The report ends with some concluding remarks.

2. 3D Printing Explained

2.1 3D printing in short

3DP (or additive manufacturing[6]) refers to several technologies that produce objects in an additive way. This manufacturing technique builds three dimensional objects by "printing" hundreds or even thousands of layers of material ("ink"), layer upon layer.

In simplified terms, 3DP is a three-step process where:

1. an image is created with the use of computer-aided design (CAD) software,
2. this image is sent to a 3D printer, and
3. the 3D printer then builds the product by depositing thin layers of material on top of one another.

In 3DP, the creation and transfer of the CAD-file is the essential component and the main difference between 3DP and traditional manufacturing. This file must be transferred, possibly cross-border, and with no transfer there will be no production.

There are at least seven different types of printing technologies available (see box), each with its own way of processing input materials ("ink") into a final product. The building technique and the choice of ink has an impact on the characteristics of the product (durability, surface finish, and details) and the application area (prototyping or functional parts). 3DP is used to directly produce products or in indirect processes in combination with traditional manufacturing techniques.[7]

3DP is taking off but it is not yet a mainstream manufacturing technique. WEF (2015) predicts that the breakthrough of 3DP and consumer products being 3D printed will come in 2025.

Note: 3DP can be compared with building an igloo where brick after brick of snow is stacked one on top of another until the snow house is built. Or perhaps more like the computer game Minecraft where brick by brick is added to build different constructions.

Facts

3D printing in detail

The 3DP process starts with the creation of a product using 3D computer-aided design (CAD). This can be drawn up by a designer or created by a 3D scan. From this model an STL (StereoLithography, 3DP's de facto standard data transmission format) is created. This model is then turned into a "build file" by "slicing" the product to the layer thickness that the 3D printer uses. The printer then uses the "build file" to print the product by adding layer upon layer of the material that the printer uses. After printing is complete, the object must be polished and excess material removed (e.g. the stand that is printed in order to keep the object from falling over during printing).

Printers use different types of materials ("ink"). Most methods rely on one type of material. Some can utilise two or more. There are today around 150 different types of material available, each of them with dozens of varieties. The material can be solid, liquid, or powder. Usable material types include plastics, ceramics, wax, sand, metals, glass, biomaterial, and carbon.

There are seven main 3DP technologies available:

i) Material Extrusion (a nozzle extrudes a semi-liquid material to build up successive object layers)
ii) Vat Photopolymerisaiton (a laser or other light source solidifies successive object layers onto the surface or base of a vat of liquid photopolymer)
iii) Material Jetting (a print head sprays a liquid that is either set solid with UV light, or which solidifies on contact)
iv) Binder Jetting (a print head selectively sprays a binder onto successive layers of powder)
v) Powder Bed Fusion (a laser or other heat source selectively fuses successive layers of powder)
vi) Directed Energy Deposition (a laser or other heat source fuses a powdered build material as it is being deposited)
vii) Sheet Lamination (sheets of cut paper, plastic, or metal are stuck together)

These seven technologies can be grouped into three groups based upon how products are built. Products are built through i) polymerisation, ii) bonding agent, or iii) melting.

Polymerisation means that parts are built through a UV-light activated polymerisation of a chemically reactive liquid material. Bonding agent means that powder material is glued together through a liquid bonding agent. Melting means that material is melted together.

Each method differs when it comes to durability, surface finish, and detailing. Polymerisation is lower in durability but give a smoother surface finish and higher detail level. The method is mostly used for prototypes and indirect processes. Melting gives opposite results and is mainly used for functional parts. Bonding agent is in-between.

Source: www.additively.com and Barnett (2014)

2.2 3D printing versus traditional manufacturing

3DP comes with a number of features that sets the technology apart from traditional manufacturing. It is in many ways a more efficient system since 3DP, as will be shown below, allows for profitable manufacturing of lower volumes and offers the opportunity to customise products to customers' individual needs. However, 3DP also has a number of short-comings and is predicted to complement rather than replace traditional manufacturing, for the foreseeable future at least.

The main features are almost no economies of scale and complexity is almost cost-free when it comes to manufacturing of goods. In traditional manufacturing, scale is central. The more one manufactures, the lower the cost per unit becomes and this leads to mass production. Complexity works the other way around in traditional manufacturing as the cost per unit rises as complexity increases. As shown in Figure 1, in 3DP the cost per unit in both cases becomes almost flat. 3DP will never reach an economy of scale of one, that is when the cost of producing one and one million is the same. In the same way, producing more complex goods will still be more expensive than non-complex goods since, for example, it is more time-consuming to correctly design complex goods. However, overall 3DP disrupts the cost per unit, not least on complex products.

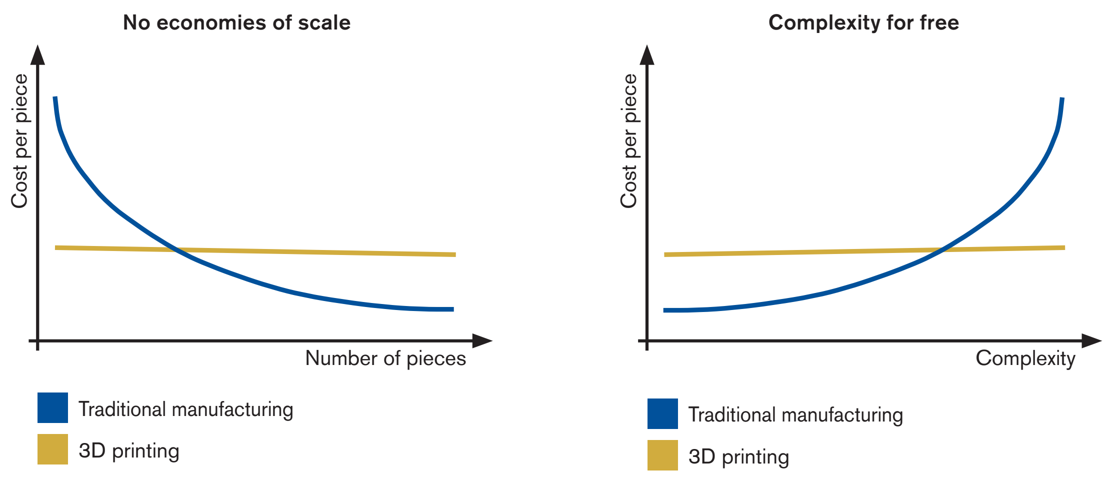
This brings forth new possibilities in the production process and manufacturing outcome. No economies of scale allows for on-demand manufacturing and on-location manufacturing, mass customisation, and the possibility of producing small quantities. Companies can replace the traditional business model of manufacturing one product in one location with splitting manufacturing to many different locations closer to the consumer. Complexity cost-free changes product designs and allows for more variety and advanced solutions. 3DP can help substitute existing products with lightweight replacements with improved performance and increased functional integration.[8]

Facts

General Electric prints jet engine brackets weighing 84 percent less than their predecessors and nozzles which are 5 times more durable due to new design features (more intricate cooling pathways and support ligaments), and two-thirds lighter than before. The nozzles have a simpler design as the number of parts used is reduced from 18 to 1. Annual fuel costs savings are estimated at 1.6 million USD per airplane.

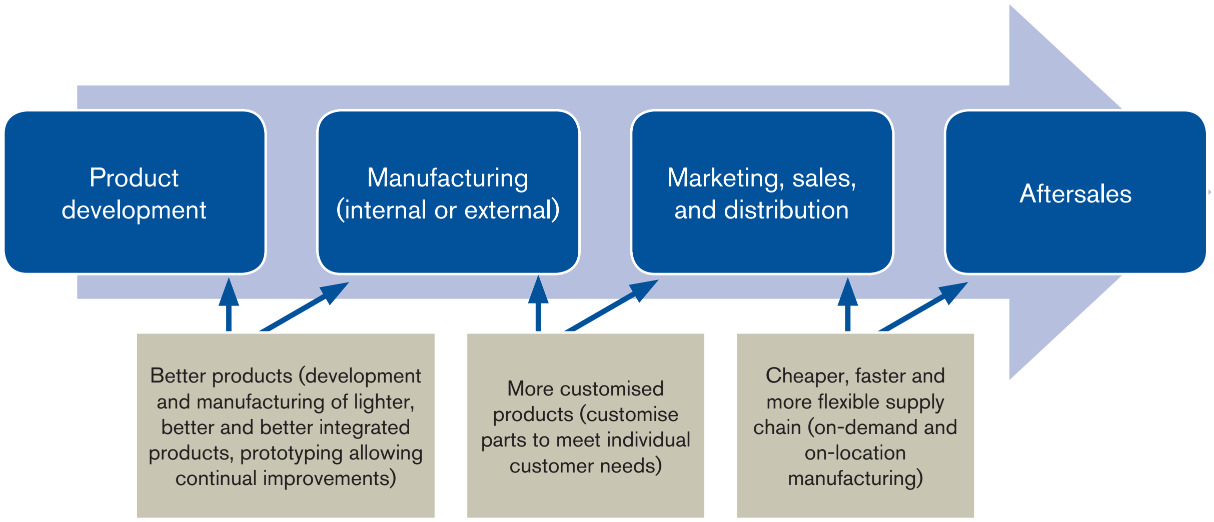
Source: GE Global Research (2015)

Figure 1: The advantage of 3D printing



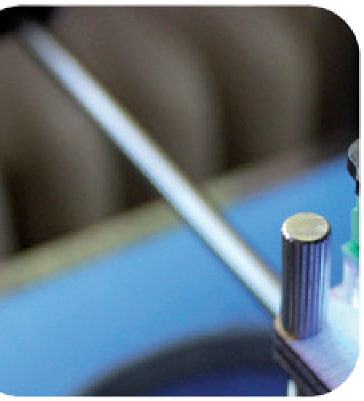
Source: Additively.com **Graphics:** National Board of Trade Sweden

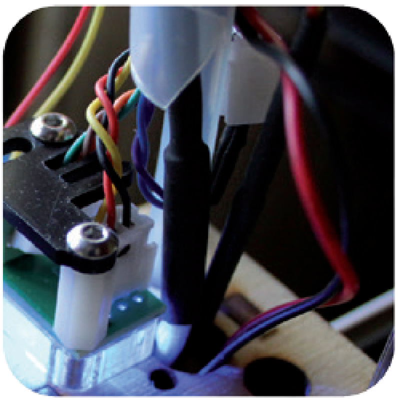
Figure 2: 3D printing advantages along the production chain



Source and Graphics: National Board of Trade Sweden

3DP allows producers to mass customise their products. Each individual product can be custom-built. In addition, 3DP allows for new capabilities when complex products can be mass produced without high fixed-cost capital investment and at a lower variable cost than traditional methods. Moreover, 3DP decreases lead time while increasing speed. This leads to shorter design times (as models can rapidly be produced and tested), process, and production cycles and products can reach markets faster. The supply chain is simplified as manufacturing can move closer to the point of demand. An added advantage is much less inventory.





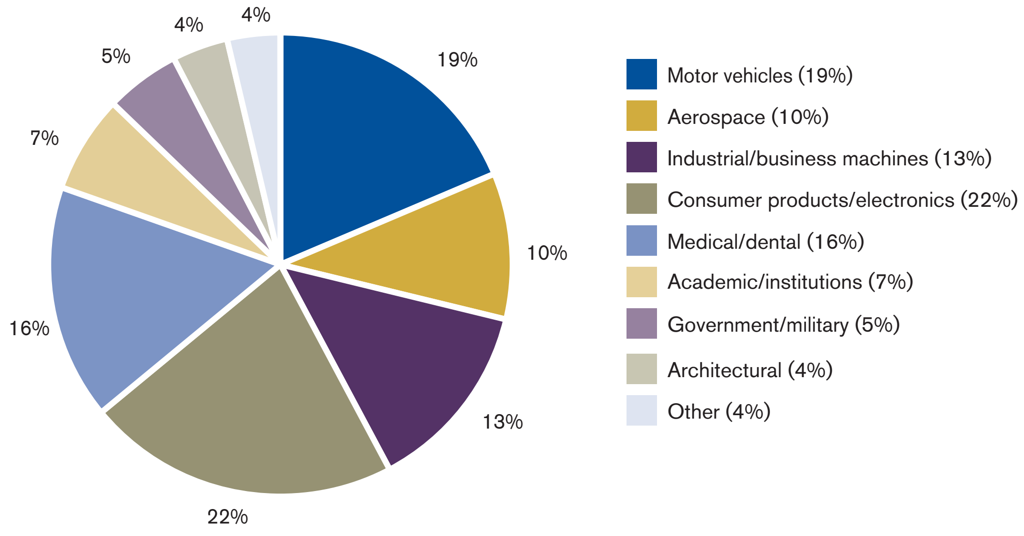
Finally, a common perception is that 3DP leads to reduced waste, especially when unused powder is being reused for successive printing and much less material is wasted.[9] However, some 3D material is toxic[10] and the environmental effect might be more complex than commonly suggested.

These advantages aside, when producing lots of products, especially with simple design, traditional manufacturing is both cheaper and faster. Traditional manufacturing also allows for building larger parts and offering greater choices when it comes to materials. For now, 3DP is and will be used where it gives an advantage, mainly for low-volume, specialised products.[11]

2.3 3D printing yesterday, today, and tomorrow

While 3DP is currently attracting a lot of attention, it is however neither a new technique nor a technique used by everyone. 3DP first saw the light of day in 1983 and came into commercial use in 1988.[12] Usage was initially limited and was mainly used for prototypes. Early users were predominantly car manufacturers, companies in the aerospace sector, and medical equipment designers. These sectors are still at the forefront when it comes to current 3DP usage (see Figure 3). Nevertheless, 3DP is becoming increasingly used in a large number of sectors, including the medical and dental sector, food, electronics, construction, clothing, and retail.[13]

Figure 3: Sectors using 3DP (2013)



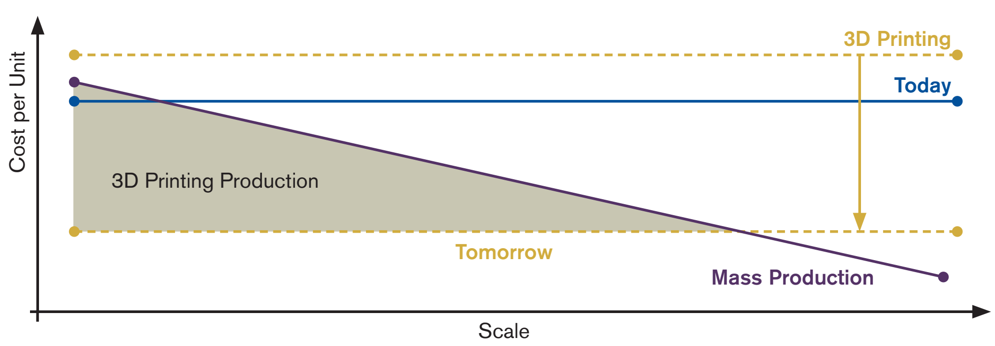
Source: Wohlers (2014) **Graphics:** National Board of Trade Sweden

3DP is sky-rocketing due to recent advances in printing speed and capabilities, coupled with lower prices of printers, which is partly driven by the expiration of a number of patents. In 2014, the global 3DP market for hardware, supplies, and services was valued at USD 4.5 billion but is predicted to increase to USD 17.2 billion by 2020.[14]

Still, as discussed above, the technology is not ripe for fully replacing traditional manufacturing. 3DP today is ideally suited for low-volume manufacturing, customised products, complex designs, high cost delivery, and urgent situations (for example, printing replacements of broken equipment). As seen above in Figure 3, most industries presented therein demand high value, complex components that are suited for 3DP technologies. For large-scale manufacturing, traditional manufacturing still has the advantage.

Technological developments and lower prices of 3D printers and ink will lead to a shift in the break-even point between traditional manufacturing and 3DP.[15] As Figure 4 shows, it is today only rational to use 3DP when manufacturing small quantities. For mass manufacturing, traditional manufacturing is preferred due to economies of scale. But moving this break-even point, by lowering the cost per unit using 3DP, will make it increasingly economically rational to use 3DP to mass manufacture items. Possibly, there will be a movement further towards mass manufacturing using 3DP, even if fully replacing traditional manufacturing is still not realistic.

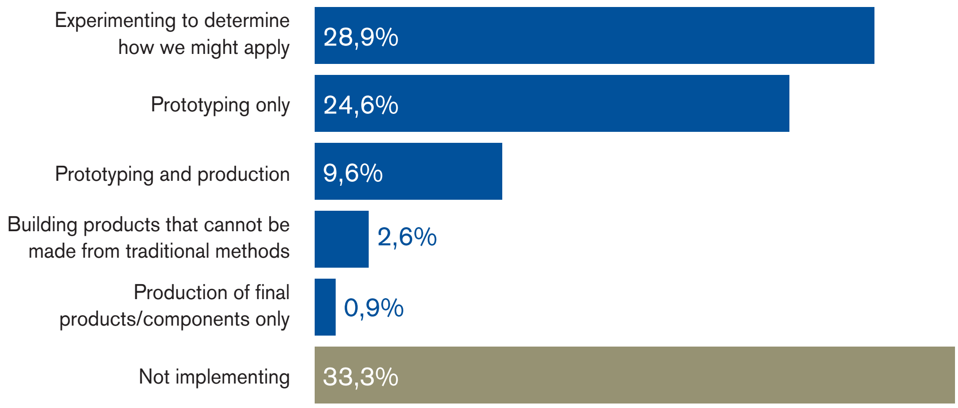
Figure 4: Moving the break-even point between 3DP and traditional manufacturing



Source: Smith (2015) **Graphics:** National Board of Trade Sweden

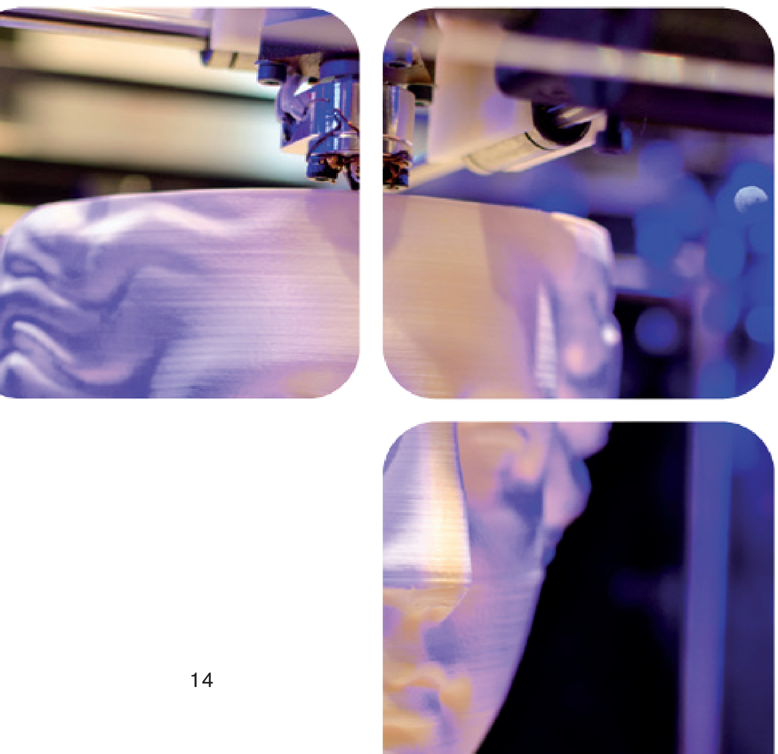
Figure 5: How companies are using 3DP

How is your company currently using 3-D printing technology?



Source: PwC (2014) **Graphics:** National Board of Trade Sweden

PwC (2014) estimates that 67 percent of manufacturers are using 3DP, out of which a large number are still experimenting in order to determine how 3DP can be used in their production processes. A quarter are using it for prototyping, while ten percent use it for both prototyping and manufacturing. Hence, the technology has moved beyond its initial focus on design and prototyping applications of 3DP toward creating more and more finished products, either as final products or as input into other goods (parts). Prototyping is still the main reason for using 3DP but manufacturing (printing) is catching up.[16]

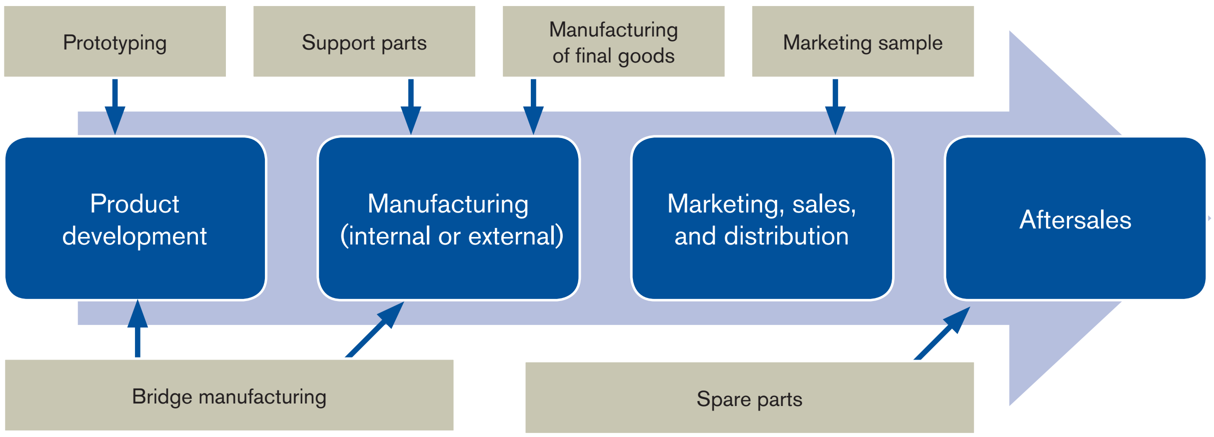


Companies are using 3DP in all parts of the production chain, as exemplified in Figure 6. From being merely for the earlier part of the production chain, it is moving more and more into latter parts of the chain and is predicted to continue to do so. It is likely that 3DP will continue to transform goods production and the application of 3DP will spread among companies and along the chain.[17]

Figure 6 shows how 3DP is used along the production chain.

- **Product development:** in the initial stage of the chain 3DP is used for prototyping (which is the main use of 3DP today) and so called bridge manufacturing (fast manufacturing of small quantities of new products in order to launch these products before investing in tools[18]).
- **Manufacturing:** during this stage 3DP is also used for bridge manufacturing. The technology is also used for manufacturing of goods, both final goods and end-use parts.[19] Manufacturers also utilise 3DP to create support parts that improve manufacturing possibilities (including 3D printed tools, patterns, and moulds).
- **Marketing, sales, and distribution:** 3DP is used for marketing samples, that is low scale manufacturing for showcasing.
- **Aftersales:** here firms use the technology to print spare parts. In this way parts can be printed urgently and reduce the need for stock. Also it makes it possible to manufacture spares for old products ("the long tail of spare parts").

Figure 6: Using 3DP along the production chain



Source: Additively.com **Graphics:** National Board of Trade Sweden

A related issue is whether companies will do the printing themselves or outsource. While differing from sector to sector, more and more of the actual manufacturing (printing) will be outsourced, especially when it comes to "end-use parts". This is done in order to access advanced equipment and expertise that does not exist internally as well as reducing investment risks. In addition, companies consider that the creation of the computer-aided design (CAD) is the part of the production chain where there is most value. Hence, they outsource a task of lesser value. Creating the CAD-files is a task that will mostly be done in-house.[20]

Clearly, 3D printing is here to stay but what will the future hold?

Predictions vary from 3DP evolving slowly but not further than today, to 3DP becoming the main manufacturing method and that resistance is futile. Part of the answer lies in the rate at which 3DP technologies improve and the willingness of end-consumers to embrace 3DP.[21] The answer will also differ between industries.

There are several issues that will influence 3DP up-take, including technological development, customer interests, internal organisational factors, and external factors like legal framework. The cost and quality of equipment as well as better, cheaper, and more readily available "ink" will decide the spread of 3DP. This is especially true when it comes to spreading the technology to SME and private individuals. Customer interests and needs are important as these will impact on the potential size of the market. Internal organisational factors are also important, especially training staff to work with and develop 3DP solutions. A specific concern here is the increased competition to find skills needed to develop 3DP usage.

Finally, a clear legal framework is seen as essential, not least in relation to questions like liability and protection of intellectual property rights.[22] Liability is perhaps the most discussed issue when it comes to 3DP. Current strict rules on liability in case of accidents are challenged in scenarios where, for example, a product is downloaded from the web and printed at home/in a print shop (see 3.1.2.). Who is liable? Is it the designer of the CAD-file? The website hosting the design? The "ink" supplier? The manufacturer of the printer of the person/company doing the actual printing?[23] This report will not delve further into this important question as it is mainly outside the scope of WTO regulation (however, see chapter 4.3.1)

So far, literature referring to legal issues has not focused on the need to clarify legal issues relating to trade regulation. This will be further discussed in chapter 4. It might be the case that a company that moves into 3DP will actually find itself in a less clear legal framework.

Hence, this study is a first discussion on this topic. But before embarking on that discussion, it is important to understand the relationship between 3DP and trade.

3. 3D Printing Changes What is Being Traded, by Whom, and How

3.1 Trade – what, where, and who?

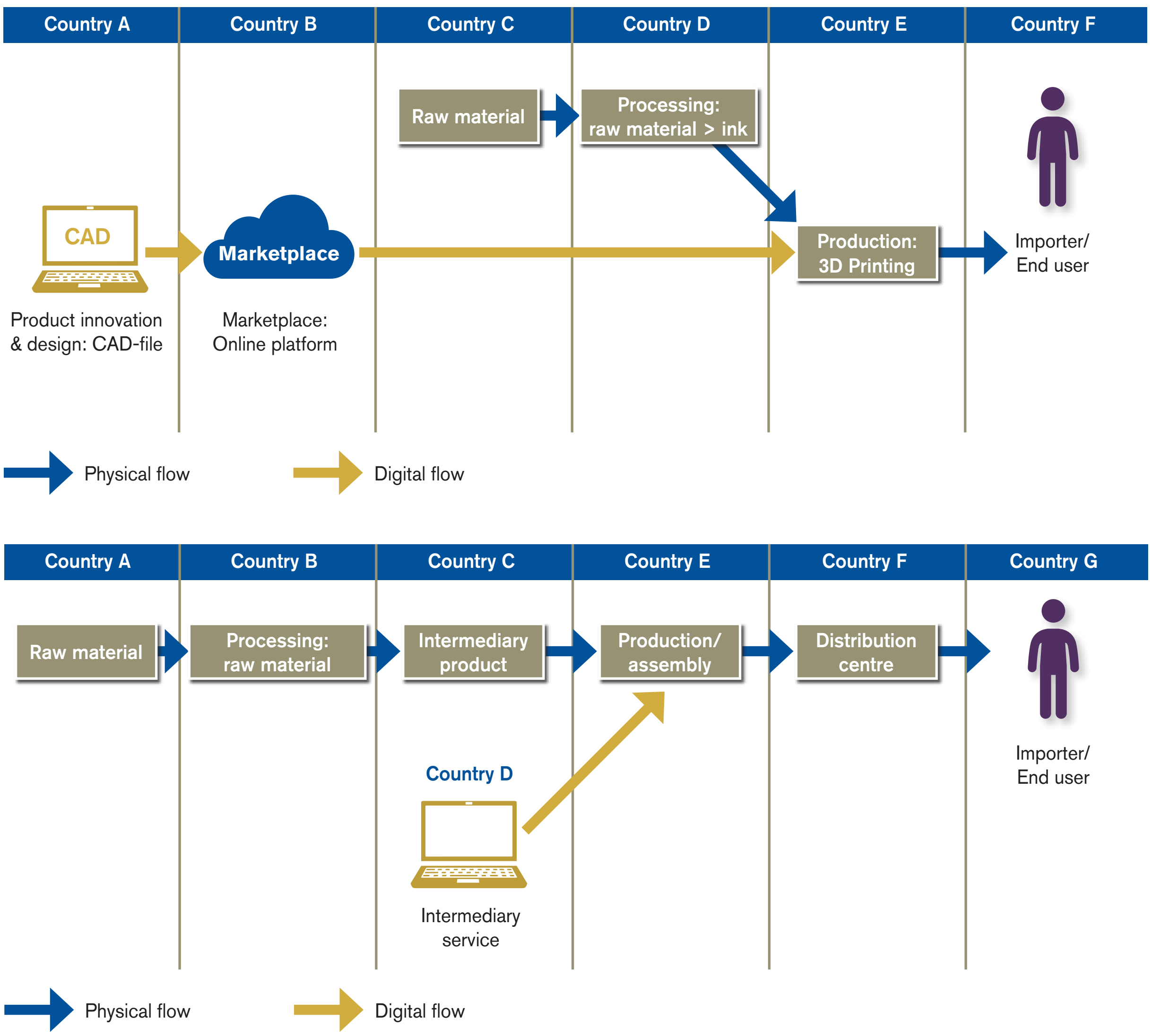
3.1.1 3D printing alters what is being traded

In a 3DP world everybody is in services. 3DP changes what is being traded, where trade takes place, and who participates. How large the change will be depends upon the uptake of the technology. This is already seen today but will be more substantial when and if 3DP really awakens.

When using 3D technology to produce goods, four "items" can be traded across borders:

1. The digital design file (the CAD-file)
2. The material ("ink") that is used when printing
3. The printed good (as printed or embodied in another product)
4. The production facility (that is, moving the manufacturing site to the country of the customer instead of selling goods cross-border).

Figure 7: Border crossings in a simplified 3DP v. traditional manufacturing scenario



Source and Graphics: National Board of Trade Sweden

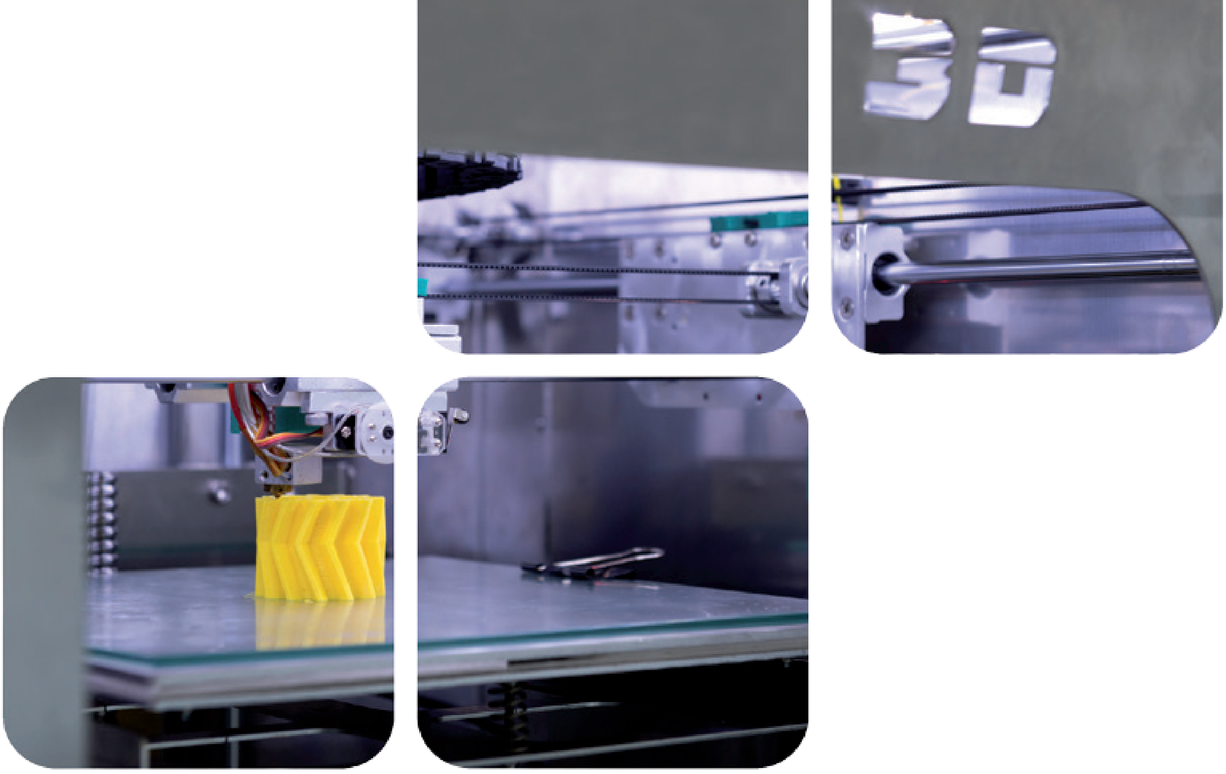


Figure 7 shows a possible 3DP value chain. Even if this manufacturing method moves production closer to the final consumer by removing intermediaries, the process may still involve a number of border crossings. In this example, a CAD-file is produced in Country A and then up-loaded to a market place in country B. A company in country E buys and downloads the CAD-file. To print the product, the company needs to import the "ink" from Country D. The "ink" consists of raw material originally from Country C. Finally, the company wants to take advantage of customisation and establishes a printing facility in the same region, but not the same country, as the final consumer. The final border crossing happens when the printed product is exported from Country E to Country F.

Obviously, Figure 7 is only one example. For all four "items" that can move across borders, there will be different variations adopted by different companies. For example, CAD-files can be produced in-house, on location, or at a research and development unit and then moved as intra-firm trade. In other instances, CAD-files will be produced by collaboration between a number of designers or "prosumers"[24], with potentially numerous border crossings as a result. In a minimalistic chain, raw material, material processing, the printing facility, and the end consumer are located in the same country.

While the variations are endless, 3DP is changing where production takes place and what is traded. It also changes who participates in production and trade. Nevertheless, on an aggregated level, Figure 7 highlights that 3DP adds more distinct services tasks, namely the creation and movement of the CAD-files. Creating and moving CAD-files are purely digital tasks and this data must in many cases be moved across borders, hereby creating cross-border data flows. Also there might be fewer border crossings, especially if a large number of intermediary products are removed and production is moved closer to the consumer. On the other hand, the creation of CAD-files, especially if done in a collaborative manner using a cloud-based solution, could involve numerous crossings. Considering this last aspect, the CAD-development, it might possibly be harder to identify the countries actually involved in the production chain.

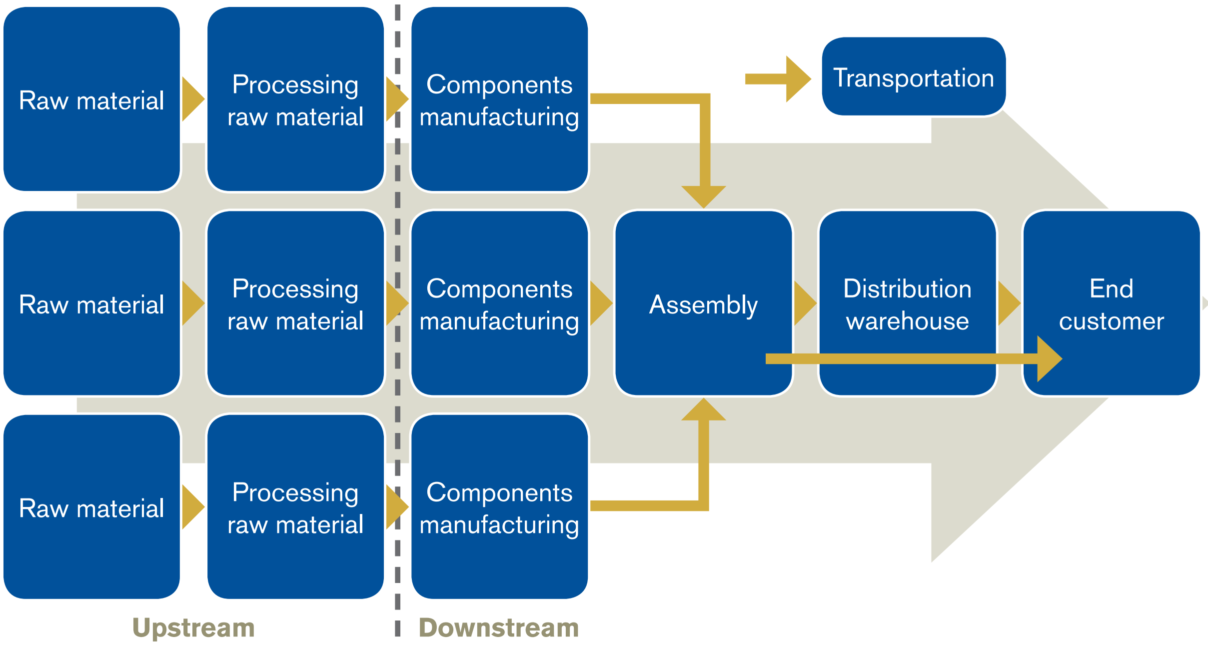
3.1.2 New participants in production and trade

Beyond a change in what is being traded, 3DP will also change how goods are produced and who participates in this production. Traditionally, trade was mainly done by large companies but due to the digitisation of production and trade, more and more small companies can now trade. 3DP is further opening the door for new companies to enter the production and trade realm, not least SMEs. Private individuals can also turn into producers. This is dependent on the transfer of CAD-files and the production and trade that follows. With no transfers there is no trade.

There are a growing number of new services suppliers entering the design phase of the 3DP process. Designers of 3D products and companies running online platforms (where designers and companies can meet and collaborate and where designs and printed goods can be uploaded, traded, and personalised) are emerging globally.

New goods producers are also emerging. In particular, a large number of smaller companies are starting to use 3DP, on their own or in a collaborative manner, to start producing and selling smaller

Figure 8: Traditional supply chain



Note: From assembly the product can be distributed directly to end customer or more commonly to the customer via distribution centres.
Source and Graphics: National Board of Trade Sweden

products or components of bigger products. As the technological development accelerates, the change in participation and production will spread out among different producers. There will still be a need for large facilities and more centralised production for certain types of goods, for example complex technical systems. In these cases, 3DP can have an impact on part suppliers, i.e. companies printing components that will go into these systems.[25]

There is a rapid emergence of print shops and FabLabs (fabrication laboratories). Print shops are 3D print shops, housing different 3D printers and specialised staff. They can be at your service and print products to consumers. FabLabs are social enterprises that aim to promote sharing and learning. In FabLabs anyone has open access to machines for digital fabrication (including 3D printers) and can receive specialised support to create or prototype goods.[26] Both can become hubs of production for a large number of consumer goods or specialised printers of specific items.[27] There will probably be limited export, instead they trade on the import side (mostly "ink").

A related new business is contract manufacturing companies that can print items on behalf of other companies. Contract manufacturers can, like the print shop, be general and print a range of different products, or specialised, focusing on a specific product. Here there will potentially be ample exports of printed goods as well as imports of "ink".

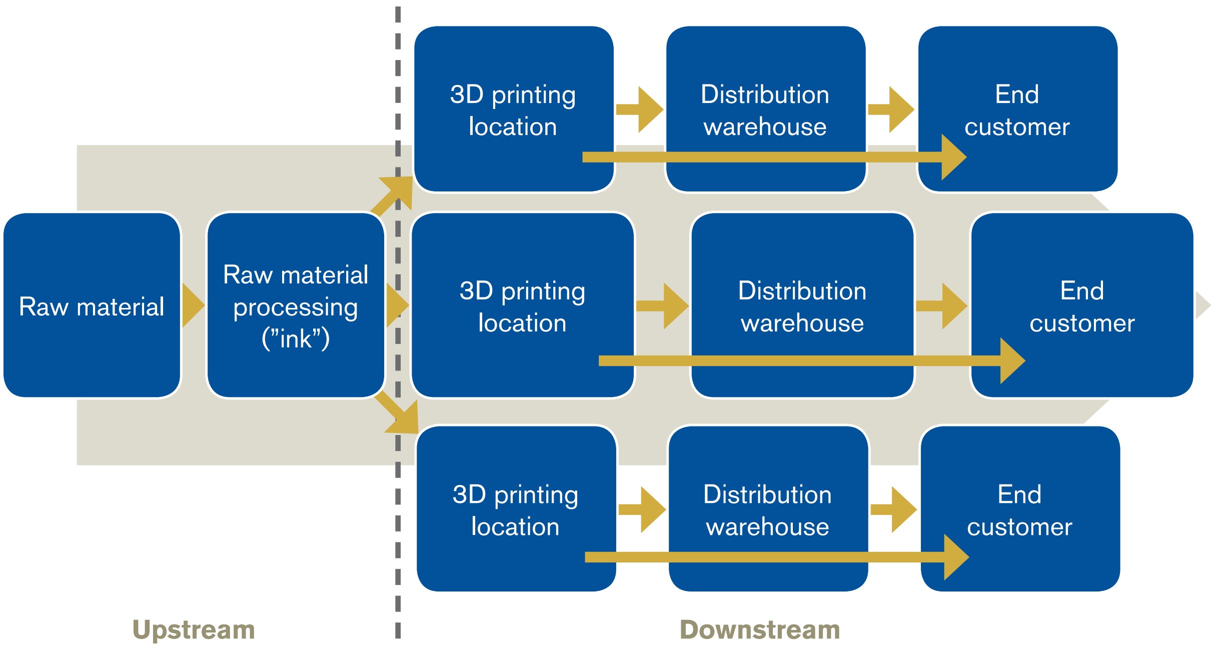
On the material side, new companies have entered the market alongside traditional raw material companies. Several of these traditional manufacturers have in turn moved into the production of the "ink". Technological progress will see new companies entering this field and it is plausible to believe that traditional raw material manufacturers will constitute a large portion of the companies that start producing "ink". The reason is that the manufacturing of "ink" is complex.[28] In addition, by becoming the material supplier, companies that produce both material and tools are given the chance of catching a part of competitors' supply chains.[29]

3.2 3D printing rewrites supply chains and trade flows

3.2.1 Up- and downstream effects on supply chains

The production supply chain is rewritten by 3DP.[30] A traditional supply chain is exemplified in Figure 8. Many companies produce goods in one location using intermediary inputs/components from a large number of sub-contractors (this Figure

Figure 9: 3DP supply chain



Note: From 3D printing location, the printed good can be shipped directly to end customer or via distribution centre.
Source and Graphics: National Board of Trade Sweden

includes three components). From the manufacturing site, companies must distribute goods to distribution centres and final customers. For large multinationals this can involve shipping products from one country, via distribution hubs, to customers all over the world.

A 3DP supply chain is quite different in nature, as shown in Figure 9.[31] The effects are not the same for the up- and downstream part of the chain (downstream meaning all tasks after raw material processing). For the downstream part, 3DP has three major effects on the supply chain:

1. It compresses the production chain by removing intermediary input/components.
2. 3DP moves away from the one product/one location principle and moves manufacturing closer to consumers (nearshoring).
3. Removing intermediaries and nearshoring reduces the need for inventory, warehousing, distribution, retail centres, and packaging.

As 3DP grows, these supply chain changes will lead to rearranged trade flows. The current flow of intermediaries, amounting to 64 percent of world trade in 2011[32], will shrink if 3DP becomes the norm. In addition, manufactured goods will not be sent from one assembly point to a large number of countries/recipients. Instead, as manufacturing is moved closer to consumption, trade in the good produced (that is, printed) will be rarer than today. In theory, bilateral trade flows between two countries could be erased.

Looking instead at the upstream part of the supply chain, there is a different shift. In this case, the processed raw material goes to a large number of 3D printing locations instead of to one location. Potentially, if 3DP becomes a household activity, the "ink" will need to be distributed in cartridges to individual homes. So for the upstream part of the supply chain, there will be an increased need for transportation and services related to moving the material (inventory, warehousing, distribution and retail centres as well as packaging). In this case, processed raw material ("ink") trade flows will change as the material will need to be distributed globally instead of, like today, to a more limited number of production facilities.

3.2.2 Supply chain participation

What will this mean for supply chain participation? On one hand, there will be a reduced need for companies supplying intermediaries. Without these intermediaries there will be less need for companies that deliver the services needed to move the intermediaries. On the other hand, new opportunities emerge along the supply chain, notably in designing computer-aided design files (CAD-files), establishing online platforms, and printing of 3D products (be it as print shops, FabLabs, or contract manufacturers). SMEs in particular might find new opportunities to participate in the production[33].

As indicated in chapter 2.3, 3DP will probably resemble traditional manufacturing when it comes to value creation and the wish to move up the value chain. There will be a lot of value in designing CAD-files and engineering and companies will probably keep this in-house. Actual printing will more often be outsourced.

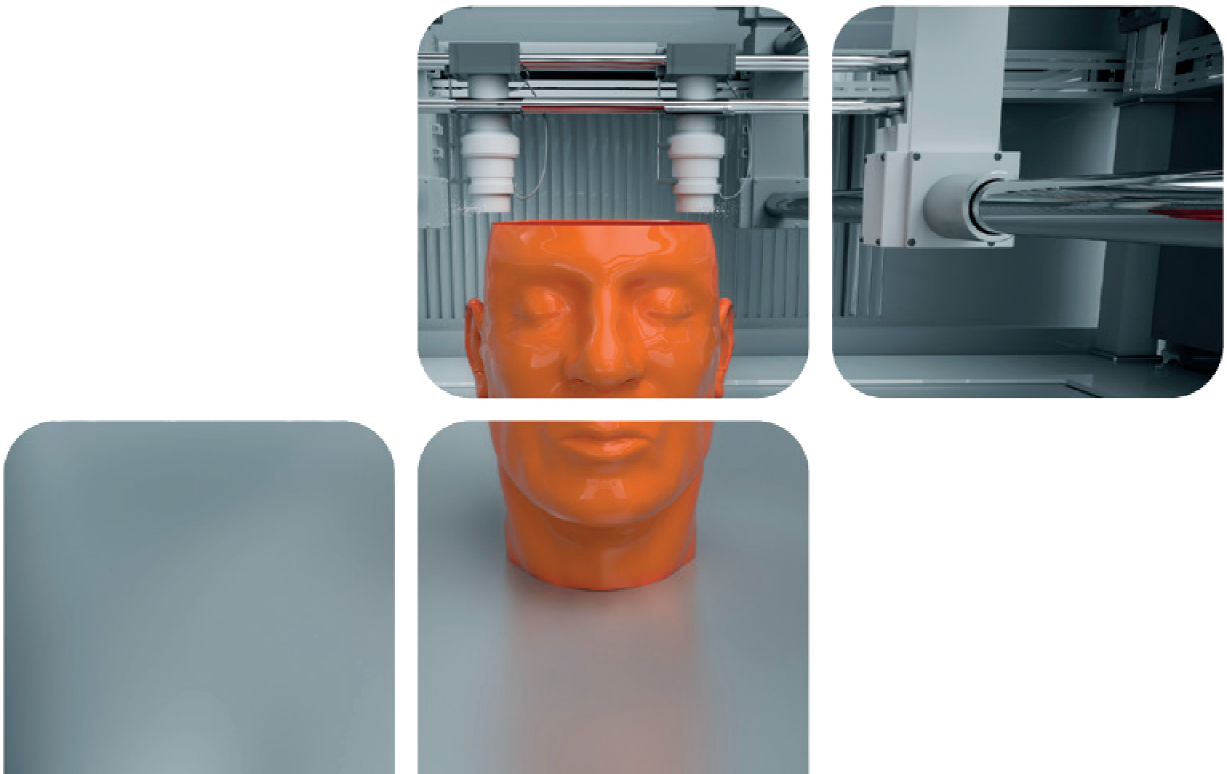
3.3 Will 3D printing mean that trade disappears?

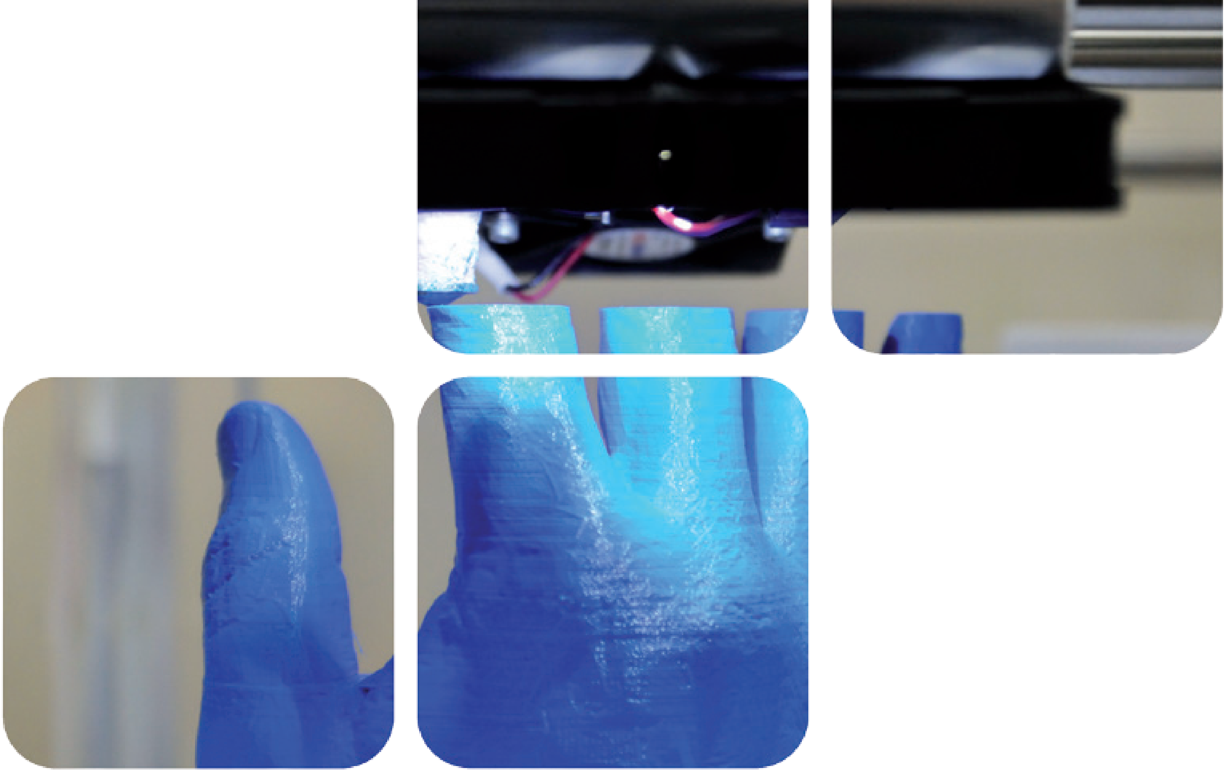
In theory, if 3DP makes all manufacturing local, then no trade in goods will take place beyond raw material and "ink". This is not likely to happen but 3DP will have clear implications on statistical measures of trade patterns as well as on our understanding of where trade takes place. A direct effect of 3DP will be an increase in estimates of services trade and a decrease in trade of manufactured goods. At the same time, it is likely that the value of total trade will decrease.

One reason for this is the disentanglement of design and engineering from the goods. Traditionally, as an "invisible" input into goods, the costs of design and engineering services are embodied in the value of the traded goods. In 3DP, design and engineering services become separate tasks and are moved from the statistical realm of manufacturing to that of services. This equates to a relative increase in trade in services. The parts of trade that will continue to be counted as goods are the printers themselves, the raw material (the "ink"), and products that contain 3D printed parts.

An additional reason for total trade to decline is actually quite real as 3DP reduces the need for trade in intermediary goods (see chapter 3.2.1) as well as some of the auxiliary services needed for trading in these goods. The main business transaction in a 3D production chain is the development and purchase of a blueprint (computer-aided design file). This means that the number of trading steps in the production chain decreases and so, consequently, does the total value of gross trade.

The shift to having a larger proportion of trade found within the realms of services will also have a negative effect on the quality and detail of trade statistics. Services trade statistics are much less detailed and reliable than statistics on trade in goods. Statistics on trade in goods are based either





on data retrieved from customs declaration systems or a very detailed and comprehensive survey. Services trade statistics are largely based on a much less detailed sample survey. The smaller number of reporting firms in the services trade statistics means both that the quality is lower and for many countries also that the trade statistics cannot be distributed among trading partners. There will also be a loss of a substantial amount of information as it will not be possible to discern which final goods the CAD-files are intended for. It might even be hard to identify these 3DP blueprints as they will end up in the much aggregated category of royalties and license fees.

Finally, 3DP will, as discussed in 3.2.1., lead to nearshoring of manufacturing. In theory, if a product is printed in all countries where there are customers, the only part of the 3DP production chain that has an international component is the raw material. The rest of the manufacturing is done locally without trade taking place.

To sum up, 3DP will lead to lower levels of goods trade and less clear knowledge of where trade takes place. Trade will not disappear. However, trade levels might go down and trade patterns will be harder to identify.

3.4 What we have learned about 3D printing and trade

Before discussing how relevant WTO regulation is in a 3DP world, here is a short recap of what 3DP is and what it means for trade development:

- 3DP is a technology where objects are built by "printing" layers of material ("ink") layer upon layer.
- The main features are almost no economies of scale and complexity is almost cost-free. The cost-advantage of manufacturing large quantities is removed and allows for profitable printing of smaller numbers. Additionally, the cost-disadvantage of making complex goods is reduced as 3DP makes it almost as easy to design complex items as it is simple ones.
- These features allow for moving manufacturing (printing) closer to the consumer (nearshoring) and for more adaption to the individual's needs.
- 3DP is growing but is not a mainstream technology. Prototyping is still the main reason for using 3DP but manufacturing (printing) is catching up.
- Replacing traditional manufacturing with 3DP will remove the need for input of intermediary goods. The only physical input is the "ink".
- Digital design files (CAD-files) are the most important input. These files tell the 3D printer what to print.
- When digital files replace intermediary goods the supply chains become shorter.
- 3DP allows for new companies (many times SMEs or private persons) to enter the supply chain and participate in production.

4. The Relevance of Current WTO Regulation in a 3D Printed World

How relevant is current WTO regulation when trade partially goes from moving physical goods to transferring digital files? Or when manufacturing (printing) moves next door to the consumer? Is the WTO regulatory framework fit for purpose or is there a need to change the rule book?

During the work with this report, the following regulatory topics have been examined:

- General Agreement on Tariffs and Trade (GATT – notably, regulation relating to customs duties/tariffs and other duties and charges (ODCs) on imports as well as rules and formalities that apply for import and export)
- General Agreement on Trade in Services (GATS)
- Customs Valuation Agreement (CVA)
- Trade Facilitation Agreement (TFA, not yet in force)
- Agreement on Agriculture (AoA)
- The Agreement on the Application of Sanitary and Phytosanitary Measures (SPS)
- Technical Barriers to Trade Agreement (TBT)
- Agreement on Trade-Related Investment Measures (TRIMs)
- Anti-Dumping Agreement (AD)
- Agreement on Subsidies and Countervailing Measures (SCM)
- Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS)
- Rules of Origin Agreement (RoO)
- Government Procurement Agreement (GPA)
- Dispute Settlement Understanding (DSU)

and there is no need to invent new rules. Also 3DP is very much about how goods are manufactured but trade in these products still mainly follows the same rules. Finally, a large number of the challenges are more related to implementation of national regulation and not the WTO rules per se.

Nevertheless, this report identifies three ways that 3DP challenges WTO rules:

1. Some WTO rules do not apply if there is no cross-border trade in goods. 3DP can lead to manufacturing being moved away from one central location to the consumer. In these cases there will be no border crossings after an item is manufactured and some WTO regulation is no longer applicable to that part of the production chain.
2. A central feature of 3DP is the creation of computer-aided design (CAD) files and how this digital task removes the need for intermediary goods. Goods-related activities are replaced by services. This leads to a situation where part of the production chain falls under a services-related agreement the General Agreement of Trade in Services (GATS) instead of goods-related agreements. Hence, there is a movement away from one set of rules to another. Alternatively, the introduction of the services tasks leads to a situation where there is a change of focus within a specific agreement.
3. Some rules might need to be revised, clarified, or developed further (fully or in part). That is, 3DP brings forth issues and challenges that certain parts of the WTO regulatory framework are not fully equipped to handle.

4.1 WTO rules apply in a 3D printing world but there are a number of challenges

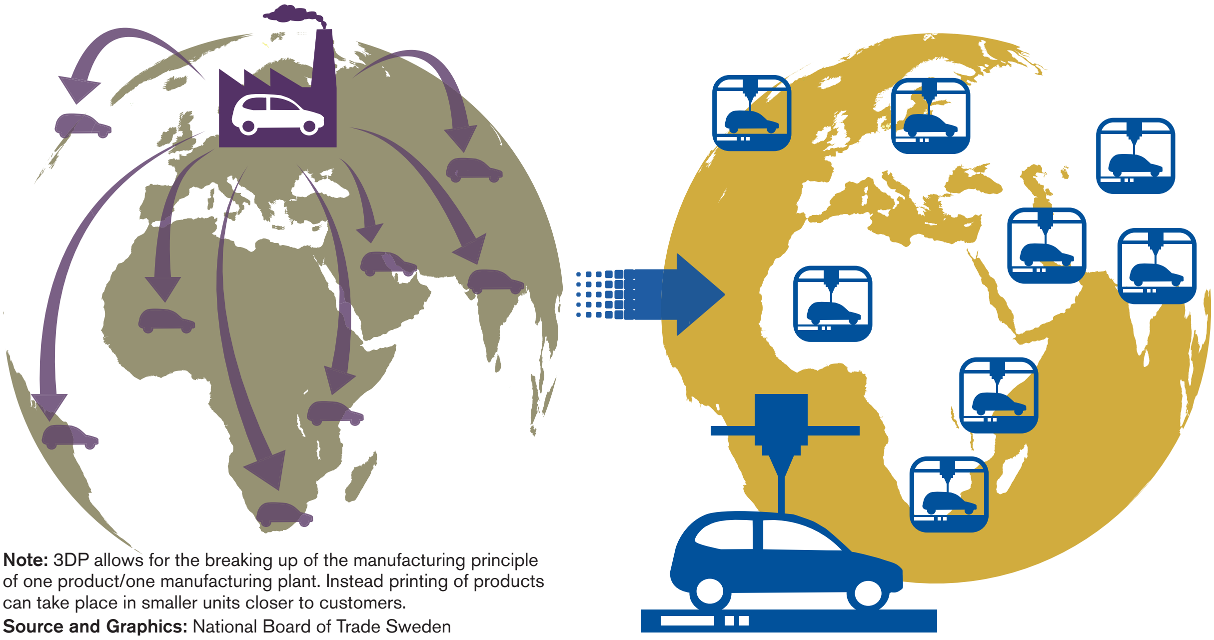
The examination of the agreements listed above reveals that current rules are by and large suitable for managing the changes brought about by 3DP. The shifts in how and where goods are manufactured and how they are sold do not lead to any major needs for regulatory changes. There are several reasons behind this finding, including the fact that many WTO rules are flexible and technologically neutral. Furthermore, central features of the 3DP process is already covered by existing rules

4.2 Some rules do not apply if there is no cross-border trade in goods

3DP changes where manufacturing takes place. The task of manufacturing final goods will move closer to the consumer. In addition, 3D manufacturing is more easily moved between locations compared to the case for traditional manufacturing.

When manufacturing moves to the same country as consumption then agreements like the General Agreement on Tariffs and Trade (GATT), the Customs Valuation Agreement (CVA), the Trade Facilitation Agreement (TFA), and market access

Figure 10: Nearshoring



Note: 3DP allows for the breaking up of the manufacturing principle of one product/one manufacturing plant. Instead printing of products can take place in smaller units closer to customers.
Source and Graphics: National Board of Trade Sweden

part of the Agreement on Agriculture (AoA) are not applicable. This is because the agreements do not apply to the products manufactured, if those products are not traded across borders (in Figure 7 on page 16, country F is removed and consumption takes place in country E).

GATT deals, among other things, with customs duties (tariffs), other duties and charges on imports as well as rules and formalities that apply to import and export. AoA contains rules and commitments for Members' tariffs on agricultural goods. CVA sets out to regulate how imported goods are valued for custom purposes and TFA aims to harmonise and standardise border procedures in order to reduce red-tape. With nearshoring reaching the point where production and consumption take place in the same country, the product that is manufactured will not be exported and no item is moved across borders. As these agreements, or parts of them, are only applicable when goods cross borders, they will cease to be relevant for the printed product if there is no such movement. However, regulations and commitments in these agreements will still be of significance for traded goods like "ink", printers, and spare parts.

Likewise, WTO members, following the principles set out in the Anti-Dumping Agreement (AD), can use so called anti-dumping measures to counter dumping (which occurs when a company exports a good at a price lower than the price it

Facts

A new digital products debacle?

"Physical goods turned into digital files"
This is a scenario that readers familiar with the e-commerce work programme in the WTO will recognise. Here there is an on-going debate on whether so called digital products should be seen as goods (and governed by the more liberal GATT) or services (GATS, being less liberal). A digital product is a good turned digital but can, after being downloaded, become physical again. E.g. a downloaded movie that can be burned onto a DVD. In 3DP, a digital file is downloaded and then turned physical. Could the same debacle emerge with 3DP?
Probably not. The main difference between digital products and 3D is that, in the latter case, the digital file is part of a production process and not for final consumption (it is a good production even if it takes place at home). The 3D-file is of no use unless being used as input into production of another object. The mere selling/exchanging of a digital file does not necessarily imply that the 3D model will actually be printed. A file can also be significantly modified by the end-user before it is printed and might also become a different object. These characteristics show that 3DP-files are services.

normally charges in its own home market). However, anti-dumping measures, and in turn the AD Agreement, become inapplicable as these measures can only be applied when a good crosses into another country. Goods that are printed by a foreign supplier but consumed in the same country cannot be subject to AD measures.

3DP poses another challenge for the AD instrument, as anti-dumping measures are imposed on goods manufactured or exported by specific companies and originating from specific countries. AD measures only target the exporters or producers that practice dumping. 3DP will make it easier to move the production away from the country that is being investigated, hereby evading AD investigations and measures. This could be done in two ways. Firstly, as described in the previous paragraph, by moving the manufacturing to the country where the product is consumed and that has introduced the AD measures. In this way, anti-dumping measures can be avoided altogether. Alternatively, manufacturing can be moved to a third country, a country that is not subject to the anti-dumping investigation. This would not be considered circumvention or customs fraud since the production is genuine in the third country.

3DP will lead to situations where some WTO rules no longer regulate or influence a specific part of the production network. However, it should be noted that other agreements might still be relevant as production moves closer to the point of consumption. Some agreements, for example, regulate how countries treat foreign suppliers in the market of printing and consumption. Additionally, other parts of, for example, the AoA will still be relevant as the agreement also contains rules on export subsidies and domestic support for agricultural products.

4.3 Some agreements, or parts of them, gain importance at the expense of others

In traditional manufacturing the main components making up the production process are physical objects, goods.[34] 3DP changes this as the technique just adds more services-related components and tasks to the production and trade mix. The central feature of 3DP is the creation of computer-aided design (CAD) files and how this digital task removes the need for intermediary goods. This way some goods-related activities in a production chain are replaced by services activities. The larger part of the process will still be goods dominated as raw material, "ink", and the end product are all goods components in the process.

As a result of the inclusion of services-related tasks, a part of production process (and the trade that takes place within this process) no longer falls under WTO's goods-related agreements. Instead this part of the production process now falls under services-related regulation.

The effect is two-fold. Firstly, there is a movement away – a switch – from one set of rules to another, namely away from goods-related agreements to the General Agreement of Trade in Services (GATS), the WTO agreement that regulates trade in services. Secondly, 3DP will also mean that there are switches within a specific set of rules as some parts become more relevant at the expense of others.

4.3.1 One set of rules becomes more important than others

Services take centre stage

The main shift is that several goods-related rules become irrelevant for the governing of parts of the production chain. Instead, as discussed above, 3DP removes intermediary goods and replaces them with a number of services-related activities (note that "ink" is still an intermediary good). Hence, the main change when using 3DP for production of goods is the introduction of services-related activities in the production chain.

3DP can involve a number of different services activities, including

a) designing and engineering computer-aided design (CAD) files,
b) transferring this digital information,
c) establishing online market-places where CAD-files can be traded (and created by collaboration between producer(s) and customer(s)),
d) establishing and running contract manufacturing facilities, including retail oriented print shops and FabLabs.

These activities are regulated under the General Agreement on Trade in Services (GATS) and this marks a clear shift in focus between agreements. Other agreements lose relevance for part of the production chain and the trade that takes place within these chains. However, it must be stressed that it is unclear how much will fall under GATS. A fundamental reason for this is that three is an unclear borderline between what constitutes a service and a good, especially when it comes to defining software. In the end it is up to WTO's dispute settlement mechanism to decide this through case-law.

Goods-related agreements will continue to regulate most stages in the 3DP scenario presented in Figure 7: The General Agreement on Tariffs and Trade (GATT), the Customs Valuation Agreement (CVA), the Trade Facilitation Agreement (TFA). These agreements will regulate raw material and "ink" border crossings as well as the printed good being exported. However, they will not be relevant for one specific part of the production process, namely where digital transfers replace the movement of physical goods (from country A to B and from B to E).

A related move towards GATS can be found when it comes to the Technical Barriers to Trade Agreement (TBT). The TBT Agreement aims to ensure that goods-related technical regulations, standards, and conformity assessment procedures are non-discriminatory and do not create unnecessary obstacles to trade.[35] 3DP technology used to produce industrial goods integrates digital services (country 1 and 2 in Figure 7). Since TBT does not apply to services, national regulators need to decide which parts of regulations are to be considered as requirements on services, thus falling outside the scope of the agreement. This means a shift away from goods regulation to services regulation.

The TBT agreement incorporates specific provisions concerning the preparation, adoption, and implementation of technical regulations, standards, and conformity assessment procedures. 3D printed products and their production method fall under the TBT Agreement. The relevance of the TBT Agreement with respect to 3DP may rise when a 3D printer, software, or a 3D printed product (including the production method) is regulated through a technical regulation or by a standard. Also the requirements (to be) put on conformity assessment should be interesting from a life cycle perspective of 3D printed products.

The requirements imposed on both the 3D printer and the end product produced by 3D printing are to be regarded as technical regulations within the scope of the TBT Agreement. This includes the requirements on

- processes and production methods,
- quality parameters, and
- conformity assessment.

If WTO member states choose to regulate these parameters nationally, the new requirements must be notified to WTO, according to the provisions in the TBT Agreement. However, without product specific international standards, product requirements are mainly found in existing legislation on specific goods and/or services.

The same effect can be seen when it comes to the Agreement on Trade-Related Investment Measures (TRIMs), the Anti-Dumping Agreement (AD), the Agreement on Subsidies and Countervailing Measures (SCM).[36]

These agreements do not apply to services and they too become irrelevant for part of the production chain. Instead this part of the chain is regulated by GATS. However, GATS lacks clear or explicit rules on issues relating to standards (TBT), subsidies (SCM), and trade-related investment measures (TRIMS). Here there may be a need for rules to be developed or clarified. This is discussed below in chapter 4.4.4.

A question of national implementation

One final aspect, beyond blurring the dividing line between what is a good and a service, is the fact that 3DP can lead to a situation where the borderline between who is the manufacturer of a good and who is a service provider becomes blurred. In relation to TBT, existing product legislation becomes difficult to apply when it comes to the question of who should be responsible for the final product. As long as there is no common view on the legislative principles this may lead to different interpretations within various jurisdictions. Here the shift from goods to services becomes an important aspect of national implementation and legislation (compare with chapter 4.5). This must be looked at when regulating and implementing rules.

4.3.2 Alternating relevance within a set of rules: changed focus in application and negotiation

Apart from shifting focus between trade rules, using 3DP also changes the focus within specific sets of rules. The effect of moving into 3DP can be that some rules must be used and applied differently than what we are used to. Alternatively, there may be a shift in what is considered to be important when negotiating new rules.

Switch in services sectors

When examining the General Agreement on Trade in Services (GATS) it is evident that there is a change in what will become important to negotiate. Central to GATS negotiations are commitments that guarantee different levels of openness in different services sectors. Commitments in sectors like design services, retail services (for online markets), and services incidental to manufacturing (contract manufacturing), will be more important as 3DP becomes mainstream. These commitments can support the development of these services activities, ensuring that markets are open and entry restrictions are removed. A commitment in GATS' mode 3 (local establishment) would ensure the right of design companies or contract manufacturers to establish themselves in foreign markets and offer their services there.

In addition to mode 3 (local establishment), the digitisation of the production chain also leads to an increased focus on mode 1 (cross-border delivery). This is discussed in chapter 4.4.3.

Facts

Four ways to deliver a service

Mode 1: Cross-border supply (e.g. phone call or sending something online).
Mode 2: Consumption abroad (e.g. tourism).
Mode 3: Local establishment (e.g. establishing affiliate in another country).
Mode 4: Temporary movement of natural person (e.g. sending an expert to another country for limited time period)

Potential shift in GPA coverage

For the Government Procurement Agreement (GPA), 3DP may have the same type of implications, as 3DP can lead to a change in the coverage. The GPA regulates purchases of goods, services, and construction services made by the public sector. Which public entities and goods/services/constructions services that are covered by the GPA depends on the commitments made by each member. In general, all goods are covered (with some exceptions) while the services cover is lower. If a public entity, instead of buying goods, purchases 3DP as a service, the purchase may no longer be covered by the GPA. Here the shift is from broad goods commitments to relatively less committed services.

A similar change in focus can occur when it comes to GPA and the application of local content requirements (LCR) in their procurements.[37] Such requirements are generally not compatible with the GPA and thus if countries want to apply LCR they must exclude them from the coverage of the GPA. Such exclusions often concern specific sectors, materials etc. For example, a good that is manufactured using traditional manufacturing techniques can be excluded from GPA if the raw material used is excluded from the GPA (due to the LCR). If, however, the same type of good is 3D printed using materials ("ink") not excluded from GPA coverage, this may mean that the good that is manufactured (printed) and then procured is no longer excluded from the GPA coverage.

Questions arise on how to prove dumping

3DP changes how the traditional requirements for imposing anti-dumping (AD) measures are interpreted and applied. While the requirements for imposing an anti-dumping measure[38] are applicable in a 3D environment, it might be necessary for an investigating authority to clarify how the determination of dumping and the calculation of a dumping margin should be undertaken when dealing with the import of 3DP products.

There is an inherent conflict in the AD-system as the rules are based on mass manufacturing and not for other types of technological solutions. One problem is the selection of the relevant producers of the investigated product. This will pose a problem since all companies using 3D-printers that can print the investigated product could potentially fall within the scope. All these companies can be potential producers.

3DP products will most likely be treated as traditionally manufactured products in investigations, since they have the same characteristics and uses. Nevertheless, from the point of view of investigating authorities, there might be situations where 3DP products are, or need to be, excluded or situations where measures only target 3DP products. The product definition will therefore continue to be essential in the investigations.

Furthermore, 3DP involves different cost structures compared with traditional manufacturing. Types and relative proportions of fixed and variable costs are different. This means that the calculation of normal value and export price can be different. Even though the analysis of injury will be done in

the same way as it is done today, several problems will emerge as industry-specific indicators will be difficult to establish when manufacturing is erratic and changeable. For example, how is production capacity and capacity utilisation established for 3DP companies? Similarly, the changes in production patterns will make the analysis of a causal link more challenging. These kinds of issues must be further investigated and resolved.

Origin of products must be proved differently
Rules of Origin (RoO) regulates how to determine the economic origin of goods. This is done through the substantial transformation criteria. This criteria can be fulfilled by one of three available methods: Value Added (VA), Change of Tariff Classification (CTC) or special technical requirement.

3DP changes the traditional production chain. Origin in a 3D world is established by determining where the last substantial transformation took place, using the three methods mentioned above. However, 3DP changes when and how these principles can be used, including, in more complex products, how value added is calculated.

Value Added (VA) method
Using the VA-method, substantial transformation occurs when significant value is added through the production process. 3DP shifts where value is added. Three shifts can be identified:

1. Removing intermediaries makes 3DP less dependent upon different imported inputs, potentially adding a larger portion of the value domestically.
2. The material used in 3D-printing can both be a simple product made up of only few inputs or the result of a complex production process made in several steps.[39] Directly related to the exclusivity and complexity of the ink is its cost, which in turn impacts the VA calculation.
3. The actual 3DP production process is simpler compared to traditional manufacturing.[40] Since the production process is less time consuming and less costly, in terms of value added, this will likely lead to a shift in focus towards the input material.

These changes lead to a need to reassess where value is created and subsequently where the substantial transformation takes place.

Change of Tariff Classification (CTC) method
With these changed conditions for the value added rule, applying CTC instead might be a more viable option. Classification of goods is based on the Harmonised System (HS). CTC establishes substantial transformation when a product is turned into another product, classified differently according to HS. Translated into 3DP terms, CTC would be fulfilled when the "ink" (classified in one specific HS-code) is printed into a product (classified in a different HS-code from the "ink").

Special Technical Requirement
Another option is to establish 3DP as a special technical requirement. Such a rule is often used for products with a unique production process which is not suitable for either a value added rule or a CTC-rule, for example textiles or chemicals. As 3DP might not be suitable for the VA or the CTC methods, this option might be the method that is most easily applied and where 3DP as a production process is by itself enough to constitute economic origin.

The application of the three methods on current and future RoO rules
All in all, RoO covers 3DP but it changes how the rules are to be applied. Today, all WTO members are free to set their own rules determining origin. There is no set of WTO rules yet. The WTO RoO agreement that is being negotiated aims at long-term harmonisation of these rules.

Even though 3DP changes the way goods are produced, the RoO can still incorporate this change without deviating from its core principles. An entirely new approach is not required but probably certain amendments and a broader scope based on the challenges described above are needed. Both national RoO and the future WTO disciplines should take this into account.

Harder to use the dispute settlement mechanism
The Dispute Settlement Mechanism (DSM) of the WTO will also experience some challenges when faced with 3DP production. The Dispute Settlement Understanding (DSU) sets out the rules and procedures for settling disputes concerning the WTO agreements. The change when it comes to dispute settlement concerns the application of this mechanism.

As explained in chapter 3, 3DP could lead to decentralised value chains with many small actors involved in the process and the manufacturing process being spread out geographically and to smaller units. This could influence the desire and possibility of bringing cases to the WTO. Would a WTO member be as willing to speak up against, for example, an export restriction if the effect only concerns a small manufacturer (perhaps a contract manufacturer) instead of a large one? Potentially this could lead to fewer cases brought before the WTO DSM. Perhaps a situation where 3DP potentially leads to less trade (as discussed in chapter 3.3) will also lead to fewer cases?

Another change could concern types of claims. 3DP alters production networks and global value chains. New questions, like for example restrictions on data flows, might receive more focus as they become more critical in the chain. Other issues, like tariffs, might become less critical. Hence we could possibly witness a switch in the substance that the DSM will have to tackle.

In addition, the shift towards a broader coverage of GATS can mean decreased legal certainty. This is due to the fact that GATS constitutes less charted territory compared to GATT. There are fewer cases, meaning that there is less robust case law.

4.4 Current WTO rules work well but parts of the framework need to be up-dated

This report concludes that there is no need for a major overhaul of the WTO legal framework in light of 3DP development. However, the analysis has found some instances where 3DP challenges certain aspects of current regulation and where there might be a need for revisiting the rules in order to revise, clarify, or further develop them. Before going on, it should be stressed that these are not new issues per se, but existing concerns, becoming more salient as a result of 3DP.

4.4.1 3D printed products might not be "like" products

An interesting question brought about by 3DP is whether a 3D printed product is the same product as one being manufactured using traditional methods? In WTO language, the question is whether the 3D printed item is "like" the traditionally produced good. This is important since WTO members are not allowed to discriminate between "like" products, meaning directly competitive or substitutable goods.[41]

If a "traditional" and a 3D printed good are not seen as "like" this would allow WTO Members to introduce discriminatory measures. The concept is of importance in the General Agreement on Tariffs and Trade (GATT) but also relevant in the Technical Barriers to Trade Agreement (TBT), and the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS).

Four general criteria for likeness were first established by a GATT Working Party in 1970:

i) the properties, nature and quality of the products, that is, the extent to which they have similar physical characteristics,
ii) the end-use of the products, that is, the extent to which they are substitutes in their function,
iii) the tariff classification of the products, that is, whether they are treated as similar for customs purposes, and
iv) tastes and habits of consumers, that is, the extent to which consumers use the products as

substitutes – determined by the magnitude of their cross elasticity of demand.

It could for example be argued that a traditional steel plate used in facial surgery is not "like" a 3D printed plate. The latter is designed to respect the physiology of bone, has a porous structure that is more in harmony with a patient's anatomy, and mechanical properties close to bone (features lacking in the traditional steel plate). One could argue that the 3D printed plate has different properties etc. (criteria number 1).

Another example could be 3DP meat (something that is not yet possible to produce for commercial purposes). 3DP meat could be made from animal cells from a real donor animal.[42] The meat could possibly, if successfully developed, have the same flavour and texture as conventional meat. However, there will be significant differences in the production process and in the impact of production. Consumers may perceive 3DP meat as something very different from conventional meat due to the production technology used.

WTO Members can refer to the criteria regarding "the extent to which consumers perceive and treat the products as alternative means of performing particular functions in order to satisfy a particular want or demand..." Hence, production method can be important, since some might argue that 3DP meat and conventional meat are not "like" products, opening up the possibility of differential treatment.

4.4.2 Insufficient rules on export restrictions can disrupt raw material and "ink" trade

Countries might be tempted to introduce export restrictions to limit the export of important 3DP input. Export restrictions are border measures put in place by a country in order to limit the export of goods. Examples are quantitative restrictions (export quotas) and export tariffs. Export restrictions can be put in place for numerous reasons, for example increased tax revenue, promotion of downstream industries, or for environmental protection.

In a 3DP world, this would concern raw material and, potentially, "ink" (hereby restricting the movement from C to D and from D to E in Figure 7). An export restriction on an essential raw material could be disruptive for companies involved in 3DP as it could restrict access to essential inputs and raise costs.

Export restrictions are only partially regulated in the WTO (without fully covering all aspects). Quantitative export restrictions are addressed under both the General Agreement on Tariffs and Trade (GATT) and the Agreement on Agriculture (AoA).[43] In Article XI there is a general prohibition of quantitative restrictions, but a number of exemptions leaves room for interpretation. Export tariffs are not bound under the GATT or the AoA.[44] They are only subject to non-discrimination provisions. This means that it is possible for Members to introduce or to raise export tariffs for raw materials that are of significance in the production of "ink" to 3DP, without this being in conflict with WTO commitments (in the same vein, export tariffs on "ink" are not bound).

If 3DP moves the production of final goods closer to the consumer, there will be, at least in relative terms, more trade in raw materials and "ink". As a consequence there could be more focus on trade policy measures affecting the price of imports of raw materials and "ink" than on measures affecting exports. In such a trade context it could be (even) more relevant than today to address the imbalance in WTO rules between import tariffs and export tariffs.

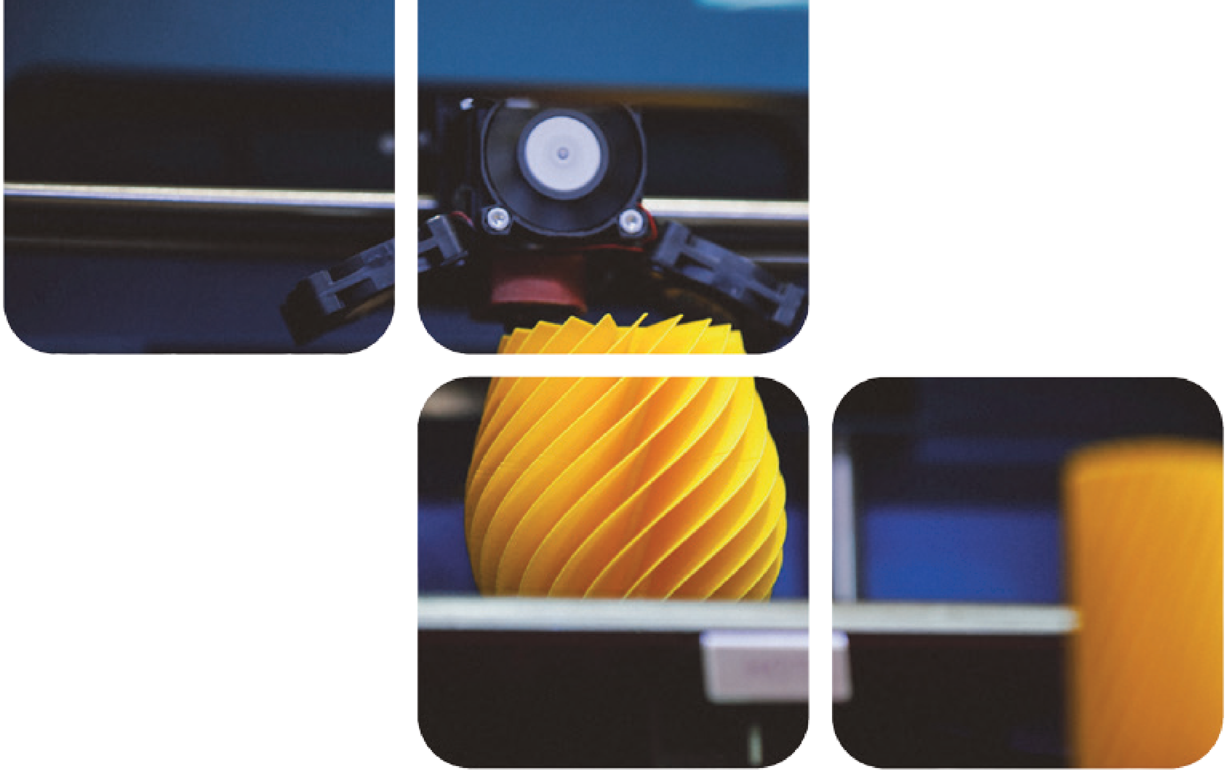
Finally, it is worth mentioning the Agreement on Trade-Related Investment Measures (TRIMs) under this heading. There might be reasons to believe that WTO Members want to introduce different types of local content requirements (LCR)[45]. This could for example be for reasons of ensuring consumption of domestically produced "ink".[46] While LCR (related to goods) are prohibited under TRIMs, enforcement is lacking.[47] These LCR can be rather disruptive and there might become a need to move towards more stern enforcement.

4.4.3 Cross-border transfers of data could benefit from WTO regulation

As mentioned in 4.3.1, the main change when using 3DP instead of traditional manufacturing methods is the introduction of more services-related activities in the production chain.

3DP can involve a number of different services activities, including

1. designing and engineering computer-aided design (CAD) files,
2. transferring this digital information,
3. establishing online market-places where CAD-files can be traded (and created by collaboration between producer(s) and customer(s)),



4. establishing and running contract manufacturing facilities, including retail oriented FabLabs.

All these services are based on digital solutions and as such they are dependent upon data being moved between different actors. Hence, transferring data is a vital aspect of the 3DP process, many times across borders (between country A and B plus B and E in Figure 7).

A growing number of WTO Members restrict the transfer of data, either by restrictions on cross-border transfers of data or by demanding that data is stored locally.[48] These measures are usually, but not always, put in place on the grounds of protecting personal information (privacy). CAD-files, the main component of 3DP, can many times include personal information and, subsequently, these national laws may become an obstacle to transfers as laws could potentially hinder the files from being transferred to other countries.

WTO does not have explicit rules[49] on transferring data across borders or data storage requirements. For 3DP to function properly, it would be valuable to introduce regulation on data flows in WTO and hereby underline the fact that data needs to be able to move freely. Meanwhile commitments in mode 1 (cross-border services delivery) are important as data flows, being cross-border delivery of services, are covered by mode 1 commitments. A commitment in mode 1 is, as such, a guarantee of the right to move data in the form of CAD-files. Obviously, the General Agreement on Trade in Services (GATS) allows for exceptions from commitments and any future data regulation in the name of protecting privacy[50]. Still the development of explicit rules on data transfers would underscore a basic assumption of free movement of, in this case, CAD-files.

Another aspect of 3DP is that it means that there will be less trade in intermediary goods. Members many times put tariffs on intermediary goods, often to create national revenue. When data transfers replace the movement of physical goods, this revenue stream might dry up. While the technology is not yet there, it is plausible that some WTO members would like to tax data flows if they could. Here the current moratorium on customs duties on electronic transmissions will be essential.[51]

4.4.4 New rules for services trade needed

As described above in chapter 4.3.1., a number of goods-related agreements (the Technical Barriers to Trade Agreement, the Agreement on Trade-Related Investment Measures, and the Agreement on Subsidies and Countervailing Measures) lose relevance for a part of the production chain and focus shifts to the General Agreement on Trade in Services (GATS). However, as GATS lacks clear or explicit rules on issues relating to standards, subsidies, and trade-related investment measures there might be a need for such rules to be developed or clarified.

To start with, it can become important to finish the on-going work on domestic regulations. The mandate for domestic regulations, as set out in Article VI.4 GATS, calls for the development of any necessary rules to prevent domestic regulations (qualification requirements and procedures, technical standards, and licensing requirements and procedures) from constituting unnecessary barriers to trade. Technical standards are important in the field of 3DP and such standards (mainly software standards) should not be created so as to close off markets or make trade more difficult.

In the same vein, the work programme on subsidies (based on the mandate in Article XV GATS) should potentially be refreshed. The same goes for the discussions on emergency safeguard measures (Article X), if considered important, to balance the weakened use of anti-dumping measures as a trade defence instrument.

Finally, the fact that the Agreement on Trade-Related Investment Measures (TRIMs) does not cover services means that a number of local content requirements (LCR), like demand for local storage of data, can potentially be introduced. Under 4.4.2., this report discussed the need for more enforcement. Here the issue is that countries can introduce LCRs that fall outside TRIMs but are not caught by current GATS rules. Examples could be demands for local storage of data (see above) and transfer of technology and know-how.[52] New rules might be needed.

4.4.5 Protection of intellectual property rights is essential but rules might be hard to apply

Intellectual property rights (IPR) protect the interests of the creator by giving them the exclusive right for a period of time to control the use of their creations.[53] The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), the WTO agreement that regulates IPR, applies both in the physical and the digital world and is therefore applicable to works produced with 3DP. Like traditionally manufactured objects, 3D created objects might be protected by IPR regulation. Also computer-aided design (CAD) files might be protected (even though it is not clear in general to what degree designs and software are protectable).

TRIPS only prescribes the minimum standard of protection; national laws govern intellectual property rights in substance. How existing laws apply to the novel aspects of 3DP can therefore differ, and each national law must be assessed separately.

The central problem is that not everything created with 3DP will be the result of the user's own ideas and creativity. 3DP allows for easy creation, copying, and modifying of both existing files and objects. There is a clear risk of unauthorised copying and usage.[54] This is nothing new, but 3DP could be a new challenge on a more decentralised level when consumers become producers. Instead of buying a finished physical object from an intermediary, an individual can download a CAD-file from a marketplace online and manufacture the object at home using a 3D-printer.

3DP challenges different intellectual property rights in different ways. Starting with copyright, infringement might be hard to determine. Copyright only protects the exact expression of the original creation, not the idea itself. It might be relatively easy to circumvent protection, especially if the design is slightly changed. Infringement of patents might be easier to determine since only the patent holder has the right to exploit the idea. Trademark and industrial designs are easy to copy and therefore infringement may be easier to determine. However, in this instance TRIPS explicitly allows for non-commercial use. Printing for personal use could therefore be permitted (and hence there will be no infringement) when it comes to trademarks and industrial designs.

A related question is to what degree objects are protected. Copying an entire product would be infringement but the question is where to draw the line. Could for instance the copying of spare parts be seen as a non-infringing repair and therefore be permitted? Or could the improvement of a product be seen as an infringement and could a slight change to the original avoid infringement?

Some practical challenges might also occur. From the user's perspective it can be difficult to find out if an object is protected. This is especially the case with copyright which is obtained automatically (and therefore there are no official registers) but also for other rights since searching these registers can be difficult. From a rights holder perspective enforcement can be difficult. Infringement can go unnoticed when made by private individuals. It might also be hard to take action against infringers since the activity might be non-commercial and small scale.[55]

IPR is a complicated area with its roots in a non-digital world. As became clear with the digitising of audio-visual products like music and films, IPR rules become harder to apply in a digital world. In that case, questions have been centred on copyrights, but in a 3DP world, with new ways of producing goods, all IPR rights will be exposed to new digital challenges. The complexity of the system, not least the existence of different regimes in different countries, will become even more evident and hence so too will potential inadequacies within the system. This in turn might create a need to re-examine national systems and TRIPS.

4.5 Many times it is all about national regulation and implementation

Reading the above, one must keep in mind that TRIPS only prescribes the minimum standard of protection that WTYO members have to ensure. It is national laws that, in substance, govern the intellectual property rights. How existing laws apply to the novel aspects of 3DP can therefore differ and each national law must be assessed separately. Subsequently, in what way members approach the challenges presented above will be very important. The level of IPR protection within a country, and differences between countries, will be crucial to the development of the 3DP industry.

This touches upon another point, namely the fact that while WTO rules are generally fit for purpose, problems can stem from how countries apply the rules in practice, and how national regulatory frameworks are developed. For example, both the Technical Barriers to Trade Agreement (TBT) and the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) still apply[56] when countries set out to regulate 3D printers, raw materials, and the 3D printed products (including processes and production techniques), such as industrial goods and food stuffs[57].

The main the question will be how countries address the new regulatory challenges presented by 3DP, in light of the lack of harmonised international requirements. There are a number of international standards available that could possibly address the regulative concerns of members. Standards are however by definition voluntary and should be used with caution as the basis for mandatory requirements. Additionally, as current 3DP standards[58] are rather generic and do not necessarily cover essential regulatory concerns, regulators need to analyse the potential gaps or risks regarding the evolving technologies and how they are used. Regulatory impact assessment and international harmonisation efforts will thus be essential in order to avoid the adaptation of measures resulting in diverging requirements and unnecessary barriers to trade.

For example, if the use of 3DP technology increases in food-related sectors, it will become important to do more research on potential health effects of 3DP food products or food contact materials, to facilitate harmonisation related regulation on the national level. This research will need to take place within the standard-setting organisations in the SPS field, in the development of new international standards, but it might also take place in member countries or research communities.

4.6 Summary of chapter 4

To summarise, the Board concludes that the WTO regulatory framework can, generally, handle the changes brought about by 3DP. However, as discussed above, there are a number of questions that ought to be further examined in order to ensure that the trade rules do not unnecessarily disrupt the development of 3DP.

Most challenges concern the downstream part of the value chain (see Figure 9) and especially the task that relates to the digital parts of the chain. That is, the fact that digital solutions replace input of physical goods is the main change that is identified. This leads to a move away from goods-based rules to services regulation, where some agreements are no longer applicable to parts of the production chain. Instead the General Agreement on Trade in Services (GATS) gets a more prominent role. How much GATS will be relevant depends upon future clarifications on the distinction between goods and services.

Other effects from 3DP stem from the possibility of nearshoring manufacturing and hereby partly removing part of the production process from the scope of some WTO rules. Again, this is the downstream part of the production chain. As for upstream tasks in the chain, the production and trade with raw materials and "ink" is less cumbersome, compared with downstream, from a trade regulation point of view.

5. Concluding Remarks

This report started with emphasising the need for legal certainty for companies and the need for a trade regime that enables production and trade in a 3DP world. The report identifies a number of issues regarding 3DP and WTO regulation. A central consequence is the possible move away from the desired legal certainty. The main culprit is the move towards the General Agreement on Trade in Services (GATS). This is due to the fact that GATS does not have the same regulatory span as GATT and other goods-related agreements. For example, GATS has less developed rules on standards and subsidies. In addition, different WTO regulations give different levels of liberalisation. The GATT grants free market access as a general principle whereas the GATS operates through a positive-list approach, implying that Member States are only obliged to grant market access and non-discriminatory treatment in the service sectors and modes of supply listed in their individual GATS Schedules. All in all, this might lead to a situation where moving to 3DP means moving away from a clear legal situation to unchartered legal territory.

Still, despite possible legal uncertainty, 3DP is making headway, and is changing how and where trade takes place, as well as who participates. New, often small, companies (including consumers turned producers) are entering the trading scene and production starts to move away from single manufacturing plants to close-to-consumers. And it is not just an issue for industrial countries but a potential opportunity for the entire world.[59]

These changes in GVC configuration and participation must be taken into account in policy making, including trade negotiations. 3DP is yet another example[60] of why trade negotiations must move into the 21st century and be based on the realities of today. To ensure that 3DP is not hindered by unnecessary barriers, trade negotiators must identify their interests and the barriers companies face. For example, due to decentralisation of production and the possibility of nearshoring, the power-houses of today might not be the main trading partners of tomorrow.[61]

There are different types of trade barriers. The reliance of the computer-aided design (CAD) files and the removal of intermediary goods leads to a situation where it become more urgent to address digital barriers and tariffs less so. And, as discussed, legal uncertainties in the WTO arena must be dealt with. There is a need to refocus and finalise some on-going WTO negotiations, notably under GATS. This includes negotiations on, for example, services subsidies and technical standards. Hence, just as trade and production is transforming, so should trade negotiations and some of the rules.

How much 3DP will change production and trade is unknown. Nevertheless, it's a safe bet that 3DP will be a natural part of manufacturing and that the technology will keep on evolving. Already 4D printing[62] is making headway, opening new doors for innovative solutions. In addition, coupling 3D printers with biosensors makes it possible to take a large step forward when it comes to personalisation of food, drugs, and clothes printing. Perhaps we are already moving beyond the *Star Trek* "replicator" towards the "Sensomatic Nutrimatic Drinks Dispenser" in *The Hitchhiker's Guide to the Galaxy*?

Whatever lies ahead, this report concludes that production and trade is changing. Companies, policy makers, and trade negotiators must adapt to the new trading landscape – resistance is useless. Luckily, from a trade policy perspective, it seems that the 20th century international legal trade framework is a sound basis for regulating this 21st century technology. There is no need for major change. Still there are a number of challenges to deal with to ensure that trade and production can prosper in a 3DP world – without facing unnecessary barriers and legal uncertainty.

References

Literature

A.T. Kearney (2015), "3D Printing: A Manufacturing Revolution"

Barnatt, Christopher (2014), "3D Printing – Second Edition", published by explainingthefuture.com

Cimino, Cathleen, Hufbauer, Gary, and Jeffrey J. Schott (2014), "A Proposed Code to Discipline Local Content Requirments", PIIE Policy Brief PB14-6, February 2014

EU Commission (2014), "Additive Manufacturing in FP7 and Horizon 2020 – Report from the EC Workshop on Additive Manufacturing held on 18 June 2014"

Ferracane, Martina F. (2015a), "Shaking and Reshaping: Industry 4.0 and Industry 4.1", Paris TechReview, Nov 30, 2015

Ferracane, Martina F. (2015b), "3D Printing: Unleashing the Magic", World Commerce Review, December 2015

Gartner (2013), "Gartner Top Predictions for 2014: Plan for a Disruptive, but Constructive Future" https://www.gartner.com/doc/2602915/gartner-top-predictions--plan

GE Global Research (2015), "3D Printing Creates New Parts for Aircraft Engines", http://www.geglobalresearch.com/innovation/3d-printing-creates-new-parts-aircraft-engines

Groth, Olaf, Espositio, Mark, and Terence Tse (2014), "Swarm Economics: How 3D Manufacturing Will Change the Shape of the Global Economy", The European Business Review, Sept 19, 2014

Harrop, Jon (2015), "Mass Produced 3D Printed Electronics", http://www.printedelectronicsworld.com/articles/8794/mass-produced-3d-printed-electronics

Hickey, Shane (2014), "Chuck Hull: the Father of 3D Printing who Shaped Technology", The Guardian, 22 June 2014

Janssen, Robbert, Blankers, Iris, Moolenburgh, Ewoud, and Bineke Posthumus (2014), "TNO: The Impact of 3-D Printing on Supply Chain Management", TNO White Paper, April 2014

Kuneinen, Eetu (2013), "Update: Andreas Forgacs on 3D Printed Meat", 3D Printing Industry blog http://3dprintingindustry.com/2013/03/07/update-andreas-forgacs-on-3d-printed-meat/

Leandri, Alban (2015), "A Look into Powder Materials for Metal 3D Printing", 3D Printing Industry blog http://3dprintingindustry.com/2015/09/17/a-look-into-powder-materials-for-metal-3d-printing/

Manners-Bell, John and Ken Lyon (2012), "The Implications of 3D Printing for the Global Logistics Industry", Transport Intelligence, Aug 2012, http://johnmannersbell.com/wp-content/uploads/2013/11/The_impact_of_3D_Printing_on_Global_Supply_Chains.pdf

Mesbah Oskui, S. et al. (2015), "Assessing and Reducing the Toxicity of 3D-Printed Parts", Environmental Science and Technology Letters, Publication Date (Web): November 4, 2015

Mungai, Christine (2015), "Could 3D Printing Revive Africa's Industrial Sector", World Economic Forum blog, Aug 12, 2015 http://www.weforum.org/agenda/2015/08/could-3d-printing-revive-africas-industrial-sector

National Board of Trade (2012), "Everybody is in Services – The Impact of Servicification in Manufacturing on Trade and Trade Policy", Kommerskollegium 2012:6

National Board of Trade (2015a), "Servicification on the Internal Market – a Regulatory Perspective. The Case of Customisation by 3D Printing"

National Board of Trade (2015b), "Online Trade, Offline Rules - A Review of Barriers to e-commerce in the EU", Kommerskollegium 2015:7

OECD (2016), "The Trade Policy Implications of Global Value Chains" [forthcoming]

Peasgood, Sean (2015), "Education Sector On Cusp of Adopting 3D Printing", Cantech letter blog, 16 March 2015, http://www.cantechletter.com/2015/03/education-sector-on-cusp-of-adopting-3d-printing/

Peterson, Steve, Bedeman, Mark, and Daria Godunova (2014), "Shifting Transport Paradigms: Understanding the Implications of 3D Printing on the Global Transportation Industry." IBM Global Business Services, September 2014.

PwC (2014), "3D Printing and the New Shape of Industrial Manufacturing", June 2014 http://www.pwc.se/sv/verkstad/3d-printing-and-the-new-shape-of-industrial-manufacturing.html

Rayna, Thierry, Striukova, Ludmila, and John Darlington (2015), "Co-creation and User Innovation: The Role of Online 3D Printing Platforms", Journal of Engineering and Technology Management 2015

Sculpteo (2014), "A Sculpteo Guide to Cost Efficiency Through Short Series Manufacturing", Sculpteo White Paper, http://www.sculpteo.com/en/get/ebook/3Dprinting_vs_injection/

Sculpteo (2015), "The State of 3D Printing: The Data You Need to Understand the 3D Printing World and Build Your 3D Printing Strategy", April 2015 http://www.sculpteo.com/en/get/report/state_of_3D_printing_2015/

Sher, David (2015), "Aniwaa: 3D Printing's Best Kept Secret Releases New 3D Printer Guide", blog http://3dprintingindustry.com/2015/09/21/aniwaa-the-best-kept-secret-in-online-3d-printing-resources-is-out-with-new-3d-printer-guide/

SmarTech Markets (2014), "3D Printing 2014: A Survey of SmarTech's Annual Market Findings", SmarTech Markets Publishing, April 2014

Smith, Rick (2015), "3D Printing And The New Economics Of Manufacturing", Forbes blog, June 2015: http://www.forbes.com/sites/ricksmith/2015/06/22/henry-ford-3d-printing-and-the-new-economics-of-manufacturing/

Stratasys (2015), "Trend Forecast: 3D Printing's Imminent Impact on Manufacturing", http://pages.stratasysdirect.com/trend-forecast

Suominen, Kati (2014), "How 3D Printing Will Overhaul Globalization as We Know It", blog post August 30, 2014 https://katisuominen.wordpress.com/2014/08/30/how-3d-printing-will-overhaul-globalization-as-we-know-it/

Torres Hildalgo, Jorge (2013), "The Regulatory Framework of Export Restrictions in WTO Law and Regional Free Trade Agreements", IES Working Paper 8/2013

Wile, Rob (2014), "We Just Discovered what '4-D' Printing is, and Our Mind is Blown", Business Insider May 8, 2014 http://www.businessinsider.com/what-is-4-d-printing-2014-5?IR=T

Wohlers (2013), "Wohlers Report 2013"

World Economic Forum (2015), "Deep Shift Technology Tipping Points and Societal Impact", Survey report, September 2015

Wright, Robert (2014), "Regulatory concerns hold back 3D printing on safety", Financial Times, November 23, 2014

Other sources

Additively.com, "Create Value with 3D Printing", Power Point presentation https://www.additively.com/en/create-value-with-3d-printing

Diegel (2015), Presentation on 3D printing by Olaf Diegel at the National Board of Trade, 2nd October 2015

Notes

1 PwC (2014)

2 An example is 3D printed electronics that went from a vision to mass production in the space of about one year. Harrop (2015)

3 Liability is discussed more in 2.3. See also National Board of Trade (2015a and b)

4 Ferracane (2015b) and Wright (2014)

5 The National Board of Trade has explored this concept in several papers, notably "Everybody is in Services" (National Board of Trade, 2012). The Board already explored the link between 3DP and servicification and possible legal effects and the implications hereof in National Board of Trade (2015).

6 Many times these terms are used as synonyms. 3DP is a term that became popular in the 90s and has been widely used since then. It has become a widespread term for low-cost 3D home printing and some of the larger commercial 3D printing systems. The term "Additive Manufacturing" was introduced later and has become the standard term for describing the technology overall, and more specifically for industrial applications and professional high-end equipment and applications. (EU Commission, 2014). Subtractive manufacturing refers to traditional methods like cutting and milling, where blocks of material are used and unnecessary excess is removed until only the desired shape remains.

7 For instance, creating master patterns (i.e. original pattern) with the help of 3DP. The 3D printed master pattern is then used for investment casting of final parts.

8 Additively.com. Sculpteo (2014) presents empirical evidence of complexity cost-free.

9 For example, A.T. Kearney (2015)

10 Mesbah Oskui et al., 2015

11 PwC (2014). Sculpteo (2014) gives empirical evidence in support of this.

12 An engineer named Chuck Hall printed a cup using a system where light was shone into a vat of photopolymer – a material which changes from liquid to plastic-like solid when light shines on it – and traces the shape of one level of the object. Subsequent layers are then printed until it is complete. The system was patented three years later. Hickey (2014)

13 Sculpteo (2015)

14 A.T. Kearney (2015). Note that there are many different predictions available. Peasgood (2015) offers a good summary of a number of forecasts. See also SmarTech (2014).

15 A.T. Kearney (2015) and Sculpteo (2014)

16 Sculpteo (2015) and PwC (2014)

17 PwC (2014), SmarTech Markets (2014), and Stratasys (2015)

18 Bridge manufacturing is used for a number of reasons, including when i) the production intent material is a 'must have' for testing purposes, ii) the quantity of parts required makes prototyping uneconomic, iii) a trial batch is required ahead of production release, and iv) there is a need for fast production of small quantities of new products in order to launch before investing in tools.

19 In 2013, end-use parts and final products amounted to 35 percent of all 3D printed goods (Wohlers, 2014).

20 Stratasys (2015)

21 Peterson, Bedeman, and Godunova (2014)

22 PwC (2014), Sculpteo (2015), and Stratays (2015).

23 Ferracane (2015b) and National Board of Trade (2015)

24 Consumer turned producers, i.e. being directly involved in the designing of goods. Rayna, Striukova, and Darlington (2015)

25 Groth, Esposito, and Tse (2014)

26 Ferracane (2015a)

27 Peterson, Bedeman, and Godunova (2014)

28 Leandri (2015)

29 For example, the engineering company Sandvik is a tool producer and also the producer of metal powders for 3DP. As competitors start using 3DP to produce their competing tools, there is a business opportunity for Sandvik to be the "ink" supplier.

30 Based on Peterson, Bedeman, and Godunova (2014), Janssen et al. (2014), and Manners-Bell and Lyon (2012)

31 Note that is an example of 3D printing a final good. The chain will be different if the printed good is to become an intermediary into another product. In this case, a simple model includes a 3D printed component that is moved to assembly (or many times printed on location).

32 OECD (2016)

33 Groth, Espositio, and Tse (2014)

34 Obviously, many services are also included as inputs. Still, traditional manufacturing centres on moving physical objects.

35 A technical regulation covered by the TBT Agreement may concern and lay out product characteristics or their related processes and production methods, including the administrative provisions. A standard, covered by the Agreement, refers to a document approved by a recognised body, which provides for common and repeated use, rules, guidelines, or characteristics for products or related processes and production methods, with which compliance is not mandatory. Conformity assessment procedures imply any procedure used, directly or indirectly, to determine that relevant requirements in technical regulations and standards are fulfilled, and include, inter alia, procedures for sampling, testing and inspection; evaluation, verification and assurance of conformity; registration and approval as well as their combinations.

36 TRIMS states that no WTO member shall apply any investment measure that is inconsistent with the provisions of Article III, National Treatment, or Article XI, Quantitative

Restrictions, of GATT and the SCM is an agreement that controls the use of subsidies. It regulates the actions countries can take to counter the effects of subsidies

37 For example the USA´s "Buy America(n)" requirements, demanding public entities to purchase only America-made products in certain projects.

38 An investigating authority must find i) that the exporter under investigation is dumping its exports, meaning that the export price of the product is lower than its normal value (meaning the price in the exporter's home market), ii) that the domestic industry of the importing country is suffering material injury or threat thereof, and iii) that there is a causal link between the dumped exports and the material injury or threat thereof, meaning that it must be the dumped imports that are causing the injury or threat thereof for the domestic industry.

39 E.g. plastic filaments (ABS and PLA) are made of one material. Powders are generally made of a mix of different materials. Also, there are a wide array of filaments (e.g. nylon- or wood-like) which are a mix of plastic and other materials.

40 In simplified terms: pushing a button involving one single production technique compared with using moulding and other more complex subtractive techniques.

41 GATT Article III.2

42 For example see Kuneinen (2013).

43 In particular Articles XI and XIII GATT and Article 12 of the Agreement on Agriculture, and arguably Article II GATT. "Article XI establishes a general prohibition of quantitative restrictions to trade, referring both to imports and exports. However, its wording is vague and leaves wide margin for interpretation. Secondly, Article II GATT constrains tariffs to the levels agreed in the schedules. However, there are no substantial commitments for export duties in these schedules. The regulation of the licensing procedures is another field where the difference between the regulation of imports and exports is evident. While exports only fall under the general provisions of Articles VIII and X GATT, imports licensing rules are extensively disciplined in the Agreement on Import Licensing Procedures." (Torres Hildalgo, 2013)

44 There are some exceptions, notably bindings made by Members that joined the WTO after 1995.

45 Local content requirements are policy measures that typically require a certain percentage of intermediate goods used in the production processes to be sourced from domestic manufacturers.

46 Suominen (2014)

47 Cimino, Hufbauer, and Schott (2014)

48 Data storage is a regulation that requires that data produced in a country is stored on servers in that country.

49 There are some rules here and there. See OECD (2016 forthcoming) for a thorough examination of this issue.

50 GATS Article XIV(c)(ii)

51 The moratorium dictates that customs duties should not be levied on digital transactions. The moratorium is only temporary in nature but has so far been renewed at every WTO ministerial meeting.

52 Cimino, Hufbauer, and Schott (2014)

53 Intellectual property rights can be divided into two branches: copyright and industrial property rights. Copyright covers literary and artistic works. Industrial property is a term for different kinds of rights, including patents, industrial designs, and trademarks.

54 Gartner (2013) predicts that by 2018, 3DP can lead to a loss for right-holders of 100 billion USD per year globally.

55 3DP might affect the way right-holders protect their intellectual property, for instance by protecting a wider range of variations to their designs and also increasing their protection geographically.

56 New regulatory measures should, among other things, i) strive towards harmonisation (preferably be based on international standards), ii) be based on risk assessment (measures should be based on scientific risk assessment, using accepted methods, if they deviate from international standards) and iii) be transparent (members should notify new or changed measures).

57 Regulatory needs when it comes to food stuffs include hygiene requirements on the raw material or on the printed food itself. Other issues that can arise are risks caused by 3DP products coming into contact with food, i.e. 3DP packaging material or kitchenware, from which substances can migrate to the food (Mesbah Oskui et al., 2015).

58 E.g. ISO 17296 and ISO/ASTM 52900 series of standards.

59 Mungai (2015)

60 Other examples are servicification, the spread of global value chains, and digitisation.

61 Groth, Espositio, and Tse (2014)

62 4D printing takes "smart" materials from a 3D printer that can assemble themselves. Instead of just printing out a chunk of shaped plastic, one can actually create shapes that a fixed 3D printing nozzle couldn't accomplish. The potential uses for this range from extreme condition architecture to adaptive infrastructure, like pipes that expand and contract depending on water volume. There is also potential in medicine: various implants could be inserted in a packed form, then take their true shape once they reach their destination. Wile (2014)

Kommerskollegium
National Board of Trade

Box 6803, S-113 86 Stockholm, Sweden
Phone +46 8 690 48 00 Fax +46 8 30 67 59
E-mail registrator@kommers.se www.kommers.se