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## The Role of Additive Manufacturing Technology in job creation: an exploratory case study of suppliers of Additive Manufacturing in Sweden

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### Abstract

This paper investigates how Additive Manufacturing (AM) technologies, as a process innovation, may contribute to a job creation. Further, the various mechanisms in which AM may contribute to an increase in job creation as well as the types of jobs are analyzed. The analysis also goes beyond AM technologies and incorporates other non-technological factors which foster job creation, i.e. higher wages in BRIC countries, lower quality in BRIC countries, and a rising demand for western-made products. The analysis is based on a case study and the data collected was through interviews with three prominent actors within the AM technologies field in Sweden: technology developers, leading suppliers and users. The main findings indicate that AM (i) contributes to job creation in both the manufacturing sector and in the service sector, (ii) does not bring back mass production jobs from emerging economies such as BRIC, (iii) contributes to job creation in product development stages (e.g. rapid prototyping), and (iv) contributes to job creation in production stages of low-volume batches mainly of complex products. The findings also suggest there are barriers for full exploitation of AM in several areas, including education systems.

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### 1. Introduction

It is extensively discussed that a new process innovation (e.g. emergence of new production methods) creates job losses and hence may even harm the economy in the short term [1]. This is because machines such as robots or 3D printers can substitute (unskilled) labor and which leads to job losses. [2]. This paper challenges this view by focusing on one particular example of process innovation, which emerged nearly three decades ago, i.e. Additive Manufacturing Technology [3] [4]. In Sweden a new strategic agenda for innovation in production was proposed in April 2014, called "Made in Sweden 2030". The agenda was developed by engineering industries in close cooperation with Swedish

Production Academy, Swerea IVF, Chalmers, KTH and IF Metall\*. The agenda identifies six key areas to strengthen production and job creation in Sweden. Three out of these six areas are related to Additive Manufacturing, i.e. flexible manufacturing processes, environmentally sustainable production, and product and production based services. Moreover, a new Swedish association is established in March 2014, aiming to increase the knowledge around Additive Manufacturing, particularly in the production stages. Their belief is that Swedish market lagging behind in comparison to the rest of the world (North America) and Europe (particularly

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Germany and UK)<sup>†</sup>. There seems to be particular interest on the role of AM on job creation. However, there are several questions to be addressed. Firstly, through which mechanisms AM may create new jobs? Is it through bringing back jobs from BRIC<sup>‡</sup>? And/or through initiating new manufacturing jobs in Sweden that never have been existed before? And/or through initiating new service jobs in Sweden that never existed before (multiplier effects)? Secondly, during which stage of production does AM contribute to creating jobs (type of jobs)? Is it in the product development stage (e.g. rapid prototyping)? And/or is it in the production stage (mass versus low volume production batches)?

The aim of this paper is to analyze the role of Additive Manufacturing technologies on job creation in Sweden. In order to do so, the paper distinguishes between various mechanisms from which jobs can be created in Sweden through AM technologies. Further distinction is made concerning the stage of the production during which AM may create jobs. Empirical analysis is based on exploratory case study interviews with three prominent actors in AM technologies as technology developers, leading suppliers and users in Sweden.

The rest of the paper is as follows. Section 2 provides a literature review aiming to identify several factors, which contribute to the rise in manufacturing jobs in western countries. Section 3 specifies the method, which is used in the empirical part of this study and also briefly describes the companies, which are interviewed. Section 4 provides the results and discussion of the exploratory case study. Section 5 concludes and provides suggestions for further research.

## 2. Literature Review

This section provides a review of literature with the aim of identifying several factors contributing to the rise of manufacturing jobs in western countries. This section is heavily based on the literature review conducted in [4], in which four driving forces of the rise in manufacturing jobs in western countries were identified: (i) emergence of new process innovations (e.g. AM technologies) in western economies, (ii) rising wage-levels in emerging economies (iii) falling quality of business milieu in emerging economies, and (iv) rising demand for western-made manufacturing. Since the aim of this paper is to highlight the contribution of AM technologies, particular attention is devoted to the first factor.

### 2.1. Role of new process innovations (e.g. AM technologies) for creating jobs

The cost of producing much smaller batches of a wider variety (with each product tailored precisely to each customer's need) is falling. The factory of the future seems to have a focus on mass-customization, rather than traditional mass-production. This allows for lesser reliance on economies of scale (available through extensive availability of cheap

suppliers in China), which could eventually lead to a rise in some manufacturing activities moving back to western countries once again. This is indeed what [5] argued: "disproportionate improvements in the technology for customization in a region can shift the manufacturing toward that region (here referring to the western countries, in particular US)". One prominent example of such "improvements in technology" is the Additive Manufacturing (AM) technology. It is a relatively new manufacturing method (process innovation) that first came into use in the late 1980's<sup>§</sup>. According to CEO of Koenigsegg (A Swedish hyper-car company), AM technology has proven useful for both (i) prototyping (faster and less waste) and also for (ii) production phase (especially in low volume and extremely complex products), because of the lower cost of production in compare with casting techniques [6]. Moreover, the AM technology provides a major gain in productivity which in turn drives down the production cost and hence may even offset the BRIC ' wage/cost advantageous [7]. In addition, combining this competitive pricing with the concept of quicker delivery to customers will provide local suppliers with an advantage over their foreign competitors who are highly competitive in their markets [8].

Moreover, the rising cost of energy and its efficacy is the major barrier for the future of manufacturing and play a significant role in shaping the geography of production. One major cost of energy is associated with waste. AM processes are shown to be capable of producing significantly lower waste compared to conventional methods [8]. Another major source of overall energy costs is the cost of transportation. Much more energy is needed to ship and deliver parts from a long distance than to ship them from a local or regional retailer and supplier. Studies indicates that due to problems such as communication and tool rework and transportation costs, the actual costs of offshore manufacturing can be higher than is estimated in many cases [8]. To sum up, the emergence of new process innovations (such as AM technologies) makes it possible to locate the manufacturing in relatively high-labour costs regions, because of the productivity gains that such new process innovation can offer. Moreover, the ability of AM technologies to meet the new trend toward mass-customized production (both for final products and prototypes) makes it an attractive option for western companies to employ. Moreover, AM technologies can boost service-provider jobs around the manufacturing jobs, i.e. multiplier effects [7]. At the end, since the type of jobs returning are different; there is a need for different skills. This implies there would be more need for high-skilled labour to operate with advanced machinery like 3D printers.

### 2.2. Role of other factors for creating jobs

Apart from emergence of new process innovations in western countries, [4] we identified three more factors contributing to the rise of manufacturing jobs in western countries. Wage-levels have always been an important motive

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for offshoring the manufacturing to a BRIC [9] [10]. Recent evidences in Denmark, Sweden and the Netherlands also suggest that the wage differential is still one of the most important drivers of offshoring to a BRIC [11]. However, a new report cites that the original labour differential that enabled the companies to move to a BRIC since the 70s is no longer present to the same extent. For instance, Boston Consultancy Group argues that wage-level in China is increasing by an average of 20 percent annually and productivity improvements are not enough to offset this labour cost. On the other hand, it is known that the average US-wage level has been stagnated for the past couple of years [12]. Hence, it is indeed anticipated that the net manufacturing cost in US and China will converge in 2015 for many industries including computer & electronics, appliances, furniture, and machinery [13]. Such a new situation definitely violates the main traditional driver of moving the manufacturing to a BRIC, i.e. wage-level differentials. Recent evidence suggests that heightened wages in some BRIC have reduced the US offshoring to those countries [14]. However, it should be noted that the rising wage-level in China may lead to lower offshoring of western manufacturing to China, but this may not necessary imply that this will lead to increases in the manufacturing in the west. Instead, higher wage level in China may lead to offshoring of western manufacturing to *other* less developed countries, like Cambodia or Mexico. This could be especially the case for capital intensive and low-skilled products that have longer life cycles.

It is shown that entry to a new market inherently involves transaction cost and such transaction cost is reduced via proper institutional setting of the host country [15]. Proper institutional setting (business milieu) was indeed one of the reasons that manufacturing has vastly moved to less developed countries (BRIC) in late 60s and early 70s [9] [10]. However, it seems the business milieu in emerging economies is not as favourable as before. First, recently there have been recurrent complains about IPR issues in China and other Asian emerging economies. It is argued that China's enforcement of its IP laws has been inadequate (e.g. lack of action against counterfeiting and piracy) [16]. Second, strikes are becoming more frequent in plants in BRIC, which makes companies to lose profits. This made, for example, Honda to give its Chinese workers a 47% wage rise after their strike in 2010 [12]. Third, the current governance practice adopted in China is dominated by a control-based model [1], which contrasts remarkably with the market-oriented model commonly used in the western countries like US and UK [17]. Considering the fact that the market-oriented governance model is recognized as the superior model [18], this simply means western companies aiming to operate in China may not expect operating in a better institutional condition than they have in their home countries. Fourth, a new labour law introduced in 2008 in China provides more protection for workers there, including the right for permanent employment after only a year of temporarily employment. On the other hand, United Auto Workers union (UAW), as one of the biggest unions in U.S, accepted a two-tier wage structure under which new blue-collar workers are paid only half as much as the longer-employed ones [12]. This obviously

provides incentives for large American car MNEs to bring back at least some portion of their activities back to home. All of these four issues can violate the previous image about proper business milieu in BRIC [16]. Such lower quality of business milieu (especially the point about the IPR problem) can be understood via the concept of *opportunism*, which [19] described it as dishonest behaviour by competing firms. According to *Transaction Cost Theory*, opportunism represents a source of transaction costs. It is one of the determinants whether firms will choose offshoring or vertical integration. Williamson [19] argued that vertical integration arises out of the need to safeguard against opportunism and contractual hazards.

Furthermore, from supply chain management studies, it has become evident recently that the original offshoring decision was usually based on a tempting per-unit price, with little consideration for total cost analysis, which includes hidden costs, such as midnight phone calls, delivery delays, IP leakage, communication challenges, and travels [20] [21]. Such total cost consideration in one hand, and boosting innovation in China (partly because of IP leakage and imitation) in the other hand has been argued to be a threat to western innovation-based competitiveness [16]. Therefore, not only lower quality of business milieu in China in recent years has blurred one of the traditional motivations to move the manufacturing to China, i.e. proper business milieu, but also their imitation skills argued to be a threat for innovation-based competitiveness of western companies.

Finally, apart from the supply side, recent studies show that demand for US-made products are already in the place. A survey of Boston Consulting Group (BCG) in September 2012 of 5000 consumers in several countries shows that more than 80 percent of U.S consumers and, perhaps more surprising, over 60 percent of Chinese consumers prefer to pay more for products labeled "Made in USA" than for those labeled "Made in China" [22]. This result can clearly create incentives for US companies to bring back some parts of their manufacturing home. In addition to such demand incentives, there are other incentives concerning the better interaction with home customers. This is particularly true for those manufacturing sectors in which the distinction between product development phase (R&D and design) and production phase is blurred [7]. These are the manufacturing sectors that require a strict connection between research, design, and production, for instance aerospace products, complex pharmaceuticals, and energy equipment. Apart from facilitating the incremental innovation, proximity to customer would ease the better service to customer, leading to higher customer satisfaction [23].

### 3. Method

#### 3.1 Research Design

The research design is based on an exploratory case study because the aim of this paper is to understand the *how* and *why* of a contemporary phenomenon, i.e. rise of jobs through AM technologies. This is particularly a suitable research

design when researchers have little control over the phenomenon [24]. A qualitative semi-structured interview has been conducted for this case study [24]. The following companies participated in the interviews; Digital Metal AB (Additive Manufacturing sector of Höganäs AB), Protech AB, and GT Prototyper AB. These companies have been selected to be interviewed, as they are either one of the prominent technology developers of AM in Sweden, or one of the leading suppliers of AM equipment in Sweden. In the former case, there are only two companies (Arcam AB and Digital Metal AB), and we selected one of them. In the latter case, there are eight main companies, who either are supplying AM technologies, or functioning as manufacturing service bureaus heavily concentrating in AM. This paper selected the two leading actors (Protech AB and GT Prototyper AB) from those eight companies for this exploratory case study interview. The three chosen companies in this paper have been providing technologies and equipment for the most of the companies and universities in Sweden, who have acquired such AM technologies. Therefore they could provide a depth of knowledge about the technology itself and the market. A brief description of each company is provided in the following Case Study section. The interviews were conducted over phone calls during May 2014 and each lasted approximately an hour. The interviews have been audio-recorded, transcribed, and spell-checked by the interviewers and validated by the interviewees. However, since empirical analysis is based on interviews, the results interpretation and generalization should be handled with caution.

### 3.2. Description of companies

Höganäs AB is a Swedish-based company who started its activities in coal mining in 1797. The company has active production in 12 plants in 8 countries, and has current business and sales in 83 countries. A branch of Höganäs AB, which offers services in the AM industry, is called Digital Metal ®. This branch belongs to the global Höganäs group, which is well known for its pioneering work in metal powders with its headquartered in Sweden. Digital Metal was formerly known as Fcubic AB, which was acquired by Höganäs AB in October 2012. Digital Metal ® focuses on four sectors as a service provider. These four sectors are: Fashion Design, Industrial Applications, Aerospace and Dental/Medical Applications (Höganäs, 2014). Digital Metal ® has developed and introduced its own manufacturing technology in the AM industry, which is called ‘ink-jet technology’. This technology uses stainless steel components in a powder form as raw material to fabricate complex metallic components. Besides, other raw materials such as titanium, silver and copper are close to commercialization [25].

Protech AB is a Scandinavian company with branches in Sweden, Norway, Denmark and Finland. It is the leading Nordic reseller of AM equipment, 3D Scanners and CAD/CAM systems since 1993. Their activities extend to providing systems for reverse engineering and quality control, rapid prototyping as well as training and support for all of their products. Protech focuses on the following sectors and offers customized products or services to them: Wood

industry, Jewelry industry, Dental industry and Insoles industry, with nine hundred customers.

GT Prototyper AB is one of the biggest service bureaus in Sweden, which focuses on the field of rapid prototyping and low-volume manufacturing of up to two or three thousand parts. They started their activities in 1994, and they predominantly center around two in house methods of Stereolithography (SLA) and Selective Laser Sintering (SLS). Their activities extend to offering vacuum and metal casting, sheet metal work, and also offering full finishing department covering basic finish to advances surface treatment, with more than two thousand customers in various industries.

## 4. Results and discussion

This section provides the result of the empirical analyzes based on interviews within the case studies. The discussion is grouped under three subheadings. Firstly, it analyzes how AM technologies contribute to job creation in Sweden through various mechanisms. Secondly, it analyzes the types of jobs that AM can create, i.e. in which stage of production AM can play role. And finally, the discussion goes beyond the technology factor (AM) and incorporates other non-technological factors. The results are summarized in Table 1.

### 4.1. How AM technologies contribute to job creation in Sweden

AM technologies currently do not bring back jobs from BRIC (Digital Metal AB; Protech AB; GT Prototyper AB), because of three reasons. First of all, rapid Prototyping has never been in BRIC like China, so it can never come back from BRIC. Secondly, mass production is still perceived to be profitable in BRIC through traditional manufacturing methods. Thirdly, there are incentives for Swedish companies to stay or move into BRIC market (Digital Metal AB). Accordingly, Digital Metal AB believes, manufacturing companies still have an incentive to move their manufacturing to BRIC markets, when they consider those countries’ market as either a market for their current products and service, or as future possible market. For instance, Digital Metal AB just opened a new facility in South Korea because there is a huge car industry market. However, one of the companies mentioned that in the future one could expect counterexamples. Protech AB mentioned that some of the labor intensive jobs, such as products which rely on labor-intensive production processes (e.g. assembling nuts and bolts in a product with 2000 parts), could be brought back to Sweden through applications of AM technologies. AM technologies enable manufacturing of the same products in a low-intensive labor manner, by fabricating them in one piece. However, this is not happening yet and it requires substantial re-design of a product. As GT Prototyper AB says: “*there is no chance in the world that one can compete with injection molding, money-wise in the case of mass production*”

AM technologies can also foster job creation in Sweden via multiplier effects in several industries. Digital Metal AB believes that many businesses or business opportunities have been created around AM technologies such as conferences

and global events, consultancy activities, CAD Systems, designing jobs and software development. Protech AB added repair shops as additional service jobs created around AM technologies. These are examples of the job that AM technology creates in the service sector though multiplier affects mechanisms.

4.2. Stages of production in which AM technologies create jobs

AM technologies creating manufacturing jobs in Sweden in both product development and production stages (Digital Metal AB; Protech AB; GT Prototyper AB). Protech AB also agrees with this statement, by providing an example concerning the rapid prototyping and production of fixtures. The former stage has been established since the 90s (Protech AB), while the latter one is the growing application of AM and it concerns the low-volume complex design products, such as Aerospace industry (Digital Metal AB; Protech AB). Manufacturing processes of a product with traditional manufacturing technologies (e.g. subtractive manufacturing) are substantially expensive due to costly tooling both from less developed countries (LDC) and Swedish manufacturing perspective. Digital Metal AB also adds that the cost of raw materials and energy is not cheap, and has not been cheap in BRIC particularly in China. BRIC manufacturers nowadays demand only high-volume production (e.g. at least 20,000 and in most cases at least 200,000) in comparison with previously demanded low-volume batches dating back to 25 to 30 years ago. In this situation, a low-volume product, such as DST\*\* products amount to 50 to 100 units per year, cannot be manufactured neither in Sweden nor in BRIC using traditional manufacturing technologies (Protech AB). Another similar example was shared by a Malmö based company regarding one of Waterco’s products (vortex generator), and one of Koenigsegg’s products (diode bar for the care front light head) (GT Prototyper AB). Therefore, AM technologies provide the opportunity to produce low-volume (and usually complex) products in Sweden. Moreover, GT Prototyper AB says AM technologies contribute to production stages of new products as designers and manufacturers in Sweden consider AM technologies as a means of production from scratch when they are designing the product. Regarding the product development stages (e.g. rapid prototyping) application of AM, GT Prototyper AB adds that those product development activities have been done in Sweden. This is due to its quick turnaround and fast delivery time. In GT Prototyper AB case, the prototyping and delivery time to their customers is around 2 or 3 days. Moreover, Protech AB also mentioned the same: AM can reduce the market delivery time and inventory stock (Protech AB). Protech AB says that there was a definite trend change for the application of AM technologies in Sweden during 2008-2009: *“in November 2009 there was a show in Jönköping and people were less talking about the machines themselves, and instead they were more talking about what these machines can do for me. This is where the market start*

*to understand that AM is not only for prototyping but also for actual manufacturing”.*

4.3. Other factors that contribute to raise jobs in Sweden

Rising wage levels were found to not be such an important factor in bringing back jobs to Sweden, especially for those industries, which are not labor intensive (Digital Metal AB). Protech AB has a similar statement: The wage level rise in BRIC cannot bring back jobs within product development stages, since the jobs concerning this stage have always been in Sweden.

Lower quality of business milieu in BRIC can have an incentive to keep the product development stage in Sweden, especially if one considers the IPR leakages in BRIC in high-tech industries (Digital Metal AB). Protech AB mentioned that; even though AM technologies are available in BRIC, it is reasonable to keep or initiate the manufacturing of products here in Sweden, such as DST products. This is mainly to avoid the complication concerning the IPR leakages. Demand for Western-manufacturing is in place: All companies think that the demand for “made in USA” is a more nationalistic and protectionism view in among US customers and this is not the same in Sweden. However, Protech AB and GT Prototyper AB think that being close to customer can facilitate the interaction with customers and enhance incremental innovation, especially in complex design products within low-volume.

Table 1- The role of Additive Manufacturing (AM) Technologies in rising jobs in Sweden

Factors influencing the rise of job	Name of Company	Types of new jobs arising in Sweden			Stages of production processes	
		Returning back	Initiate for the 1 <sup>st</sup> time (Manuf.)	Initiate for the 1 <sup>st</sup> time (Service)	Product Development	Production
1. AM Technologies	Digital Metal	NO	YES	YES	YES	YES
	Protech	NO	YES	YES	YES	YES
	GT Prototyper	NO	YES	NO	YES	YES
2. Rising wage levels in LDCs	Digital Metal	NO	YES	NO	NO	NO
	Protech	NO	YES	NO	NO	YES
	GT Prototyper	NO	NO	NO	NO	NO
3. Lower quality of business milieu in LDCs	Digital Metal	NO	YES	NO	YES	NO
	Protech	NO	YES	NO	YES	YES
	GT Prototyper	NO	YES	NO	YES	YES
4. Demand for Western-manufacturing is in place	Digital Metal	NO	NO	NO	NO	NO
	Protech	NO	NO	NO	YES	YES
	GT Prototyper	NO	NO	NO	YES	YES

5. Conclusion and future work

The aim of this paper was to analyze the role of Additive Manufacturing technologies on job creation in Sweden. Two research questions are addressed, aiming to investigate the various mechanism in which AM contribute to job creation as well as the types of jobs are analyzed. In response to RQ1: ‘How do AM technologies contribute to job creation in Sweden?’. The authors conclude that AM technologies contribute in job creation both in manufacturing sector and service sector. In the service sector, job creation is mainly through multiplier effects. The paper also concludes that AM

\*\* www.dst.se

technologies do not bring back mass production jobs from emerging economies. In response to RQ2: ‘in which stage(s) of production do AM technologies create jobs?’, this case study concludes that AM technologies foster job creation both in product development stages (e.g. rapid prototyping), and in manufacturing stages of low-volume batches, mostly for complex products. The former stage has been established since the 90s (Protech AB), while the latter one is the growing application of AM and it concerns the low-volume complex design products, such as Aerospace industry.

This study also highlights some barriers and future opportunities to improve the importance of AM technologies in job creation. According to Protech AB, there was a considerable investment in universities and research institutes in 2008-2009, for instance, in Germany and UK concerning the application of AM technologies in production (e.g. fixtures and end-used parts), whereas this was not the case in Sweden. GT Prototyper AB similarly noted that there is still not enough formal education and training in the universities, therefore the company needs to train its employees in house, e.g. basic training on machines. This currently leads Sweden to slightly lag behind Germany and the UK.

In order for further exploitation of AM technologies in Sweden, Protech AB suggests that there are two important areas that Swedish universities need to carry out research and education as there is little knowledge available about them. These two areas concern the pre-production and post-production stages of a part with AM. The pre-production stage deals with how one can design a model to be manufactured with AM systems regardless of limitation of design with traditional manufacturing technologies as a means of production. Similarly, GT Prototyper AB also faces big challenges when designers still think of limitations with respect to subtractive manufacturing (e.g. Injection Molding) design principles while they are designing products which would now be produced with AM technologies. The post-production concerns the quality control. It means how one can ensure the repeatability of a fabricated part, i.e. to what extent two fabricated parts with two machines of the same type have the same quality (Protech AB).

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