May additive manufacturing technologies boost manufacturing reshoring?

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Abstract

Additive manufacturing technologies (AMTs) are expected to heavily influence the competitiveness of companies. According to some scholars, the adoption of AMTs may have a relevant impact on the location of production activities. This paper aims to verify if AMTs may act as an enabling technology for manufacturing reshoring.
The paper adopts an explorative research approach based on eight companies which based their reshoring decisions on the adoption of AMTs. Findings seem to confirm the research hypothesis. At the same time, AMTs seem to influence the firm's decision in terms of governance mode.

Keywords: Reshoring, Additive manufacturing, 3D printer

Introduction

The "Industry 4.0" scenario is attracting increasing interest from scholars, practitioners and policy makers. In this scenario, additive manufacturing technologies (AMTs) and 3D technologies (3DTs) are expected to promote the most relevant technological change. After years where 3DTs have been used mainly for rapid prototyping purposes, now they are more and more affecting the value chain as a whole. According to some scholars and practitioners, the adoption of 3DTs may have a relevant impact on the location of production processes of many manufactured goods (Berman, 2012; D'Aveni, 2013; Gress and Kalafsky, 2015; Laplume et al., 2016).

After decades of offshoring strategies, recently industrial companies have been deciding to revise their decisions in terms of manufacturing activities' locations. Among other alternatives (such as further offshoring and near-reshoring), they are also considering the manufacturing reshoring option, i.e., "a voluntary corporate strategy regarding the home country's partial or total re-location of (in-sourced or out-sourced) production to serve the local, regional or global demands" (Fratocchi et al., 2014).

The paper aims to contribute to the academic discussion on "right-shoring" verifying the hypothesis that 3DTs may act as an enabling technology for making resilient manufacturing reshoring decisions. In order to investigate this topic, the following research questions are considered:

a) Do benefits characterizing AMTs adequately match motivations pushing companies to reshore their manufacturing activities to the home country?

b) Are 3DTs and reshoring decisions diffused in the same set of industries?

c) Does AMT adoption influence the governance mode (insourcing vs. outsourcing) of the reshored manufacturing activities?

In order to shed light on such research questions, an explorative approach based on secondary data will be implemented, referring to evidence collected in the Uni-CLUB MoRe Reshoring dataset (Ancarani et al., 2015; Fratocchi et al., 2014; 2016).

Findings from the analyzed case studies seem to confirm the idea that AMTs may influence the firm's decision-making process to repatriate production to the home country. At the same time, such technologies seem to influence the adopted governance modes after reshoring implementation.

Literature Review

Manufacturing Reshoring

An increasing number of scholars have been investigating the reshoring topic since 2007 (for an up-to-date literature review, see Fratocchi et al., 2016; Stentoft et al., 2016; Wiesman et al, 2017). Very few contributions were devoted how managers make decisions to repatriate offshored activities and how they put these decisions into practice (Bals et al., 2016; Foesrtl et al, 2016 ; Joubioux and Vanpoucke2016). Most of the extant literature is focused on pinning down motivations influencing the reshoring decision making process (Bals et al., 2016; Fratocchi et al., 2016; Stentoft et al., 2016). Among them, the adoption of production technologies is referred only to automation (Arlbjørn and Mikkelsen, 2014, Stentoft *et al.*, 2016) while AMTs were never cited as a reshoring driver.

Another relevant issue in terms of reshoring decision making process is represented by the choice of governance mode implemented after the repatriation decision. Scholars do have not a unanimous position on this issue. More specifically, some authors only consider the case of reshoring choices coupled with insourcing strategies (Ellram, 2013). On the contrary, Gray et al. (2013) clearly pointed out that decisions regarding manufacturing locations and governance mode are two different managerial decisions. Finally, Arlbjørn and Mikkelsen (2014) and Bals *et al.* (2016) recognise the two decisions are conceptually independent but retain they are "interconnected".

Additive Manufacturing

AMTs have been developed since the 1980s and were generally adopted for rapid prototyping, i.e., a fast build-up of prototypes and mock-ups. However, over the past few years, 3DTs have been increasingly adopted for producing industrial parts in several industries (Oettmeier and Hofmann, 2016). Compared to other, more "traditional" manufacturing technologies AMTs offer distinct advantages which may be grouped according to the following categories (Tab. 1): a) Cost; b) Customer perceived value; c) Design/product features; d) Eco-sustainability.

The manifold set of advantages offered by AMTs induces companies to adopt them in several industries (Table 2). Further insights, in terms of diffusion of 3DTs, were recently offered by Laplume et al. (2016) who classified sectors in terms of their readiness to implement such technologies: a) already adopting AMTs on a large scale (5 out 24 ISIC sectors); b) expected to adopt them in the near future (10); c) not adopting (presently and in the near future) (9). Comparing the classification proposed by

Laplume et al. (2016) with the findings summarized in Table 2, it seems those authors assumed a more restrictive approach, such as in the case of aerospace and automotive industries.

Table 1. Benefits of 3D technologies

Benefit category	Benefit	Reference
Cost	Reduction of production costs (especially for small batches) since no object-specific tools are needed	D'Aveni, 2015; Mellor et al., 2014; Petrick and Simpson, 2013; Rylands et al., 2016
Cost	Reduction of production costs since assembling is no longer required	D'Aveni (2015)
Cost	Possibility to economically manufacture complex and unique parts	Berman, 2012; Holmström et al., 2010; D'Aveni, 2015; Cohen et al., 2014; Petrick and Simpson, 2013; Rylands et al., 2016
Cost	Less waste material, reducing costs and improving the firm's eco-sustainability	Khan and Mohr, 2016; Kothman and Faber, 2016; Janssen et al., 2014; Mellor et al., 2014; Mohr and Khan, 2015
Customer	Possibility to economically offer customized outputs	Cohen et al., 2014; Petrick and Simpson, 2013; Mellor et al., 2014; D'Aveni, 2013; 2015; Mohr and Khan, 2015
Customer	Enabling printing at point of purchasing/consumption	D'Aveni, 2013; Mohr and Khan, 2015; Petrick and Simpson, 2013; Rylands et al., 2016; Tassey, 2014
Customer	Shortening lead times and lowering inventories since (printing "on demand")	D'Aveni, 2013; Petrick and Simpson, 2013; Mellor et al., 2014; Mohr and Khan, 2015
Design/Product features	Rapidity in design changes	Berman, 2012; D'Aveni, 2015; Mellor et al., 2014; Mohr and Khan, 2015
Design/Product features	Increased freedom of design	D'Aveni, 2013; Cohen et al., 2014; Mellor et al., 2014; Mohr and Khan, 2015; Petrick and Simpson, 2013; Rylands et al., 2016
Design/Product features	Improve the optimization and integration of mechanical, thermodynamic and electrical functions of products	Glasschroeder et al., 2015
Design/Product features	Possibility to produce lightweight objects (grids and hollow structures)	Petrovic et al., 2011
Design/Product features	Building in a single piece objects formerly composed of several subcomponents	D'Aveni, 2015
Eco-sustainability	Improve eco-sustainability of final products (e.g. lighter automobiles or airplanes will be more fuel-efficient)	D'Aveni, 2015
Eco-sustainability	Less waste material, reducing costs and improving the firm's eco-sustainability	Khan and Mohr, 2016; Kothman and Faber, 2016; Janssen et al., 2014; Mellor et al., 2014; Mohr and Khan, 2015

Table 2 Industries adopting additive manufacturing

Industry/Product	Reference
Aerospace	Atzeni and Salmi, 2012; Mellor et al., 2014; D'Aveni, 2015; Gress and Kalafsky, 2015; Oettmeier and Hofmann, 2016
Automotive (including parts)	Ruffo et al., 2007; Bradshaw et al., 2010 ; Cooper et al., 2012 ; Mellor et al., 2014 ; D'Aveni, 2015
Camera lens accessories	Bradshaw et al., 2010
Construction	Kothman and Faber, 2016
Electronics (including PCs)	Mellor et al., 2014; Gress and Kalafsky, 2015; D'Aveni, 2015
Filter and filtration solutions	Rylands et al., 2016
Food processors (replacement parts)	Bradshaw et al., 2010
Footwear	Berman, 2012
Household (replacement parts)	Bradshaw et al., 2010
Houseware	Berman, 2012
Lighting	Mellor et al., 2014; D'Aveni, 2015
Medical & dental applications (e.g. Dental crown, Hearing aids molds, Prosthetic limbs)	Berman, 2012; Mellor et al., 2014; D'Aveni, 2015 ; Oettmeier and Hofmann, 2016
Measurement devices	D'Aveni, 2015
Sunglasses	D'Aveni, 2015
Telecom infrastructure	D'Aveni, 2015
Wallpaper	Rylands et al., 2016

Additive manufacturing technologies and the Supply Chain

Oettmeier and Hofmann (2016) assume 3DTs have an effect on all the three elements comprising an SC (Lambert, 2014): a) network structures (member firms and their interconnections); b) processes (e.g., supplier relationship management, manufacturing flow management); c) components (e.g., IT infrastructures). This has relevant consequences, among others, for governance mode (make vs. buy) and location (home vs. host countries) decisions. With respect to the former (governance mode) there is no convergence among scholars. For instance, Berman (2012) and D'Aveni (2015) maintains that AM adoption induces firms to prefer outsourcing, since product designs are easy to share. In contrast, Ruffo et al. (2007) found the make option to be preferred, not only in terms of mere production costs but also of logistics costs and delivery time.

There is no convergence among scholars also when considering the geographical location of manufacturing activities. Some of them point out that 3DTs will greatly reduce the need for labour. Therefore, low wage countries will lose their competitive advantage, while shipping times and costs for producing offshore will remain (Berman, 2012; D'Aveni, 2013; Kianian et al., 2015). At the same time, Mohr and Khan (2015) suggest that the adoption of 3DTs will permit a quick response to changes in customer demand both in terms of volume and product features. Therefore, it is preferable to locate production activities in the home country, reducing lead times, which in turn mitigates the risk of product obsolescence. On the other hand, Gress and Kalafsky (2015) maintain that at least large batch and cost-sensitive productions will still remain in low cost countries. Finally, D'Aveni (2015) states that firms adopting AMTs will decide where to print their products "in real time, adjusting shifts belonging to issues like labour costs and printers efficiency.

Methodology

The earlier conducted literature review clearly shows the relevance of research questions addressed in this paper. In order to investigate them an appropriate research methodology need to be adopted. Yin (1994) states that the research strategy must be chosen on the basis of three elements: a) type of research question; b) extension of investigator control over investigated behavioral events; and c) nature of events with respect to the time dimension (historical vs. contemporary). Since there is limited empirical evidence on the research questions investigated in this paper, this research is exploratory in nature. At the same time, the analyzed events are contemporary and the investigator has no control over them. Therefore, a research methodology based on secondary data is well suited to meet the requirements of answering the proposed research questions. This research methodology was already applied both in International Business and in Operations Management research (Roth et al., 2008). Among sources of secondary data, a specific role is played by written records such as newspapers and magazines, which have been considered particularly useful when no other sources are available (Cowton, 1998; Franzosi, 1987; Mazzola and Perrone, 2013).

Secondary data adopted to investigate the proposed research questions belong to the "Uni-CLUB MoRe reshoring" dataset (Ancarani et al., 2015; Fratocchi et al., 2014; 2016). To the best of author's knowledge, the Uni-CLUB MoRe dataset is the most relevant in terms of the number of single reshoring decisions and home/host countries. Information was gathered from several sources: historical archives of relevant national and international business newspapers (e.g. Financial Times) and business magazines (e.g. The Economist); white papers by major consulting companies; and the only public database currently available (www.reshorenow.org). For each observation, information was recorded on the company involved; company size; industry; headquarters country of origin; year in which backshoring strategy was implemented; year in which offshoring strategy was implemented; "abandoned" host country; declared motivations for backshoring. At the end of 2015, manufacturing reshoring decisions sampled in the dataset totaled 728 belonging to 600 companies, since some of them implemented more than one decision. Reshoring firms are widespread among 29 home countries. With respect to host countries, almost one half (350) of the sampled decisions belongs to China and the other 84 the rest of Asia. In terms of industries, firms belong to 22 manufacturing sectors but the first five account for more than half (370) of the total amount of firms' decisions. Reshoring motivations were declared by more than three out of four sampled companies; such firms cited from one to ten different drivers. Among these drivers, eight firms explicitly cited the adoption of AMTs. Finally, with respect to the governance mode adopted before and after the manufacturing reshoring decision, the majority of sampled firms do not implement any change. More specifically, 385 out of 661 decisions (for which governance mode data are available) prefer to maintain the insourcing mode, while 138 continue to outsource their production activities even after repatriation.

In order to investigate the first proposed research question (eventual matching among 3D benefits and reshoring motivations) a two steps approach will be implemented:

a) first of all, each driver included in the dataset is compared with the benefits of 3DTs found in the extant literature. This will permit the author to verify – at a general level – if AM has the potential to support reshoring strategies;

b) secondly, attention will be focused on the eight companies declared to have adopted 3DTs. More specifically, the reshoring motivations they cited will be compared with AM benefits reported in the extant literature. In so doing, a more fine-grained check will be implemented to shed new light on the research questions under investigation.

The main features of the sampled companies are summarized in Table 3.

Table 3 Characterization of reshoring companies adopting 3D technologies

Year of reshoring	Company name (Group Holding)	Home country	Product line	Host "left" country	Motivations
2013	Element 14	UK	Computers (Raspberry Pi)	China	Lead time; Made in effect
2013	Brinsea Product	UK	Egg incubators	China	Lead time; Lower stock holding; Difficulties in insuring overseas activities
2013	Maxx Sunglasses	USA	Sunglasses	Taiwan	Lead time; Strategic elements;
2014	Nomiku	USA	Kitchen appliance for sous vide cooking technique	China	Interactions R&D/Mfg; Higher product innovation
2014	Thinklabs Medical	USA	Medical stethoscope	China	Interactions R&D/Mfg; Higher product innovation
2014	Inertia Racing Technology Wheels	USA	Bicycle components (carbon based wheels)	Taiwan	Prototypes' costs
2017 (planned)	Reebok (Adidas Group)	USA (D)	Athletic shoes	China	Lead time; Proximity to customers; Production costs

Source: Uni-CLUB MoRe reshoring dataset

With respect to the second research question (industry matching) the two steps research method described earlier is implemented with some adjustments. Specifically:

a) first of all, the eventual matching among industries cited in AM literature and those sampled in the adopted dataset is verified. After this, industries characterized for the presence of both phenomena will be evaluated in terms of their magnitude, i.e., the relevance of reshoring decisions made by them with respect to the total repatriation decisions;

b) attention will then be paid to the eight companies declaring to have adopted 3DTs, whose industries will be verified by those of the extant literature.

With respect to the governance mode, attention will be directly paid to the sampled companies, verifying the eventual changes in governance mode between the offshoring and reshoring phases.

Results

Referring to the first research question, Table 4 summarizes the results of the comparison between reshoring motivations and AMTs benefits. Findings shows that eight out of 28 motivations sampled in the Uni-CLUB MoRe reshoring dataset are matched by at least one of the 3DTs benefits cited in the extant literature. Moreover, for another four drivers the matching is deduced on the basis of the technical features of 3DTs; for instance, the possibility of reducing/eliminating assembling activities determines the reduction in transport costs for components, supporting the "logistic costs" reshoring driver. Therefore, it seems there is a relevant overlapping between reshoring motivations and 3DTs' benefits in at least half the analyzed cases. In this respect, it must be noted that such an overlap is referred to in nine out of the ten most relevant motivations in terms of reshoring firms' citations. Consequently, it seems – at least at a general level – that AM may represent an enabling technology for manufacturing reshoring.

In order to verify such a finding from a more fine-grained perspective, it is useful to pay particular attention to motivations (other than 3DTs adoption) declared by eight firms belonging to the Uni-CLUB MoRe reshoring dataset. The most cited reshoring driver (five out eight companies) is lead time; this finding is particularly interesting since this driver is one of the most cited in both the extant literature on AMTs (D'Aveni, 2013; Mellor et al., 2014; Mohr and Khan, 2015; Petrick and Simpson, 2013) and in the dataset evidence (15% of total decisions for which motivation was available). A further reshoring motivation declared by the eight sampled companies belongs to more strategic issues. More specifically, two companies pointed out that AMTs not only make it possible to reshore their manufacturing activities but also to modify their product range and/or their market positioning. This finding is coherent with the most recent debate regarding manufacturing reshoring, where some scholars stated that such a decision is "more than just a geographical shift of operations. It is also a reconfiguration of systems" (Mugurusi and de Boer 2014, p. 275) and/or a firm's strategy redefinition (Grandinetti and Tabacco, 2015).

Focusing attention on the second research question, Table 5 summarizes the results of comparisons, in terms of industry diffusion, of the two investigated phenomena: AMTs and manufacturing reshoring. Data clearly show a complete overlapping in eight out of the ten more relevant industries in terms of reshoring evidence. At the same time, it is confirmed that the Laplume et al. (2016) expectations, in terms of adoption time of 3DTs, are quite restrictive with respect to the extant literature and theoretical findings.

When considering the eight sampled companies, the huge variety of applications of AMTs is confirmed once more. They belong to five different industries which all are among the ten most relevant in terms of number of manufacturing reshoring decisions. Therefore, a diffused matching in terms of industries among the two analyzed phenomena seems confirmed.

The last investigated research question regards the governance mode, i.e., the choice among insourcing and outsourcing in both the offshoring and reshoring phases. As pointed out earlier, in the extant literature there is no convergence among scholars. At the same time, empirical data regarding manufacturing reshoring (UniCLUB MoRe dataset) induce us to expect that companies do not change their governance mode while transferring manufacturing activities back to the home country. Quite unexpectedly, analysis of the eight companies offers totally different evidence. More specifically, in the seven cases for which data are available (excluding Brinsea Products), the governance mode adopted during the offshoring phase was outsourcing; on the other hand, after the manufacturing reshoring all companies shifted to the insourcing alternative.

Conclusion

In this paper the eventual contribution of 3DTs to the manufacturing reshoring phenomenon has been investigated. Due to the lack of earlier studies on this issue, an explorative research approach was adopted based on secondary data. More specifically, three research questions were developed, the first of which is regarding the eventual relation between AMTs' benefits and manufacturing reshoring motivations. The latter were defined on the basis of an in-depth literature review, while the former were extracted by the most up-to-date and internationally widespread available dataset on reshoring decisions (Uni-CLUB MoRe reshoring). A further investigation was then developed, analysing the eight cases of companies belonging to the dataset which declared having implemented 3DTs. Findings of both analyses provided evidence that there is a large overlap among 3DTs' benefits and reshoring motivations.

Table 4 Comparison among reshoring motivations and AM benefits

#	Reshoring motivation	3D benefit (literature review)	Other explanations
1	Logistics costs		Adopting AM assembling is no longer required, the number of components will decrease reducing transportation needs
2	"Made in" effect		The product is printed in the home country so it may benefits from the "made in" effect
3	Offshored production of poor quality		Additive manufacturing may assure product quality and its replicability
4	Labor costs differentials' reduction	Reduction of production costs since assembling is no longer required	
5	Total cost of ownership	Reduction of production costs (especially for small batches) since no object-specific tools are needed	
		Reduction of production costs since assembling is no longer required	
		Possibility to economically manufacture complex and unique parts	
		Reduced waste material, reducing costs and improving the firm's eco-sustainability	
6	Increasing service level	Possibility to economically manufacture complex and unique parts	
		Rapidity in design changes	
		Enabling printing at point of purchasing/consumption	
		Possibility to produce lightweight objects (grids and hollow structures)	
7	Lead time	Shortening lead times and lowering inventories since (printing "on demand")	
8	Government aids		Some countries developed a specific policy to support diffusion of AM technologies (see, for instance, Gress and Kalafsky, 2015; Kianian et al., 2015; Rylands et al., 2016)
9	R&D vicinity to production	Rapidity in design changes	

The second research question is regarding the eventual homogeneity among the industry diffusion of two investigated phenomena: 3DTs and manufacturing reshoring. Also in this case, findings based on the analysis of the extant literature were compared with both the information contained in the manufacturing reshoring dataset and that of the eight sampled companies. A diffused overlapping among these three elements was also found in this case.

Finally, the third research question is regarding the eventual changes in governance modes implemented in the offshoring and reshoring phases. While AM scholars did not reach a homogeneous theoretical position (e.g. Berman, 2012; D'Aveni, 2015; Ruffo et al., 2007), evidence from the Uni-CLUB MoRe dataset supports the idea that no changes are usually implemented. On the contrary, evidence deriving from the eight investigated case studies shows the adoption of 3DTs induces the re-insourcing of the manufacturing activities after the reshoring implementation.

Tab. 5 Comparison among manufacturing reshoring and AM technologies diffusion among industries

NACE Code	Sub-code	Description	No. of decisions	% of total decisions	Industries/Products cited in AM literature	Diffusion according to Laplume et al.'s (2016) classification
26		Manufacture of computer, electronic and optical products	97	13.3%	YES (several products)	In the future
27		Manufacture of electrical equipment	78	10.7%	YES (Lighting, Domestic appliance)	In the future
14		Manufacture of wearing apparel	67	9.2%		In the future
28		Manufacture of machinery and equipment n.e.c.	64	8.8%		Today
32		Other manufacturing	64	8.8%		Today
	32.1	Manufacture of jewellery, bijouterie and related articles	2			
	32.2	Manufacture of musical instruments	5			
	32.3	Manufacture of sports goods	11			
	32.4	Manufacture of games and toys	23			
	32.5	Manufacture of medical and dental instruments and supplies	10		YES	
	32.9	Other manufacturing n.e.c.	13			
29		Manufacture of motor vehicles, trailers and semi-trailers	53	7.3%	YES	In the future
25		Manufacture of fabricated metal products, expert machinery and equipment	50	6.9%	YES (Houseware)	In the future
15		Manufacture of leather and related products	49	6.7%	Yes (Footwear)	Never
22		Manufacture of rubber and plastic products	42	5.8%	YES (Filters)	Today
30		Manufacture of other transport equipment	35	4.8%	YES (Aerospace)	In the future
31		Manufacture of furniture	32	4.4%		In the future
10		Manufacture of food products	22	3.0%		In the future
20		Manufacture of chemicals and chemical products	19	2.6%		Never
21		Manufacture of basic pharmaceutical products and pharmaceutical preparations	11	1.5%		In the future
23		Manufacture of other non-metallic mineral products	11	1.5%		Today
13		Manufacture of textile	10	1.4%		Never
24		Manufacture of basic metals	9	1.2%		Never
17		Manufacture of paper and paper products	5	0.7%	YES (wallpaper)	Never
16		Manufacture of wood and of wood products and cork, except furniture	4	0.5%		Never
11		Manufacture of beverages	3	0.4%		Never
18		Printing and reproduction of recorded media	2	0.3%		In the future
12		Manufacture of tobacco products	1	0.1%		Never
Total			**728**	**100.0%**		

The main limitation of this paper is the impossibility to generalize findings, due to its explorative nature. However, it does shed new light on an under-investigated topic which seems very relevant for both International Business and International Operation Management scholars. In this respect, AM and manufacturing reshoring phenomena are expected to influence the competitiveness of industrial companies in the near future. Further research should be implemented in order to enlarge evidence and reach more generalizable findings.

In terms of implications, those regarding policy makers seem to be particularly relevant. In the extant literature there are several examples of national policy supporting the diffusion of 3DTs (see, among others, Gress and Kalafsky, 2015; Kianian et al., 2015; Rylands et al., 2016). At the same time, there is evidence also of various legislations supporting manufacturing reshoring (Bailey and De Propris, 2014a, b; Fratocchi et al., 2015b; Guenther, 2012; Livesey, 2012). In analysing such policies, some communality emerges, such as aids for human capital building and/or incentives for renewing production systems. Therefore, an effort should be implemented to integrate these two types of public policy.

Finally, with respect to managerial implications, it must be pointed out that the decision making and implementation phases are extremely critical for both the strategic decisions: adoption of AMTs (Rylands et al., 2016) and manufacturing reshoring (Bals et al., 2016). Therefore managers should develop specific decision supporting tools; among them, the Total Cost of Ownership (Ellram, 1995) seems to be one of the most useful approaches.

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