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Open Production: Chances for Social Sustainability in Manufacturing

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Abstract

The participation of spatially distributed individuals in the whole production cycle is feasible through the transnational possibilities of information, communication, and production technologies. To a much greater extent than ever before value creation is generated through the use of knowledge. Open Production is a concept which enables companies to apply the criterion of openness to the whole value creation process. These new patterns of value creation (bottom-up-economics) enable the realization of small firms, which combine the three production factors - labor, ground and capital - in one stakeholder. This article addresses the social aspect of sustainability and gives an overview on the chances of micro-factories to foster social sustainability in manufacturing and redirect development efforts towards a collaboration-oriented rather than a growth-oriented approach.

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Keywords: Social Sustainability; Open Production; Value Creation; Square Foot Manufacturing; Micro-Factories; Knowledge Transfer

1. Introduction

The on-going paradigm-shift in value creation (individualized production, co-creation experience, production networks etc.) is initiated by new technologies: information and communication technologies (ICTs) as well as manufacturing technologies. Based on these new technologies people are able to produce in networks, which in the last instance can be defined as a big virtual factory, decentralized and locally steered by autonomous stakeholders, highly modular and, insofar, adequate to the strategy of adaptability of production systems [1].

The actual paradigm shift in value creation has to be taken into account in order to reflect the new opportunities with regard to social sustainability. In fact, micro-factories are a technological enabler of the paradigm-shift. They enable anyone to manufacture almost anything as they represent small production systems [2]. Until now, micro-factories and their chances for social sustainability is a rarely considered topic [3,4]. Social sustainability enlightens one dimension of the concept of sustainability. Hence, which opportunities can be derived from the new manufacturing technologies in terms of social sustainability to foster participation and empowerment and which limitations exist? Is there a possibility to increase the amount of opportunities to participate?

Thus, in this paper the opportunities arising from micro-factories for a socially sustainable value creation are analyzed against the background of bottom-up-economics. First, the paradigm-shift in manufacturing technologies is reviewed and the concept of Open Production is presented. It enables companies to open their value creation processes, structure and artifact. Secondly, the main criteria of social sustainability are reflected according to micro-factories and finally the strategies to apply the new technologies for social sustainability derived from the concept of Open Production, opportunities and problems, are discussed based on practical examples in the field of development cooperation. Insofar, this article delivers a positioning of the possibilities of micro-factories in the wider context of bottom-up-economics and derives opportunities and problems of the micro-factories according to social sustainability.

2. New patterns of value creation

The shift from an industrial to a knowledge society is marked by the increasing value of the factors ‘knowledge’ and ‘information’ in proportion to the classical production factors

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(capital, machines etc.) [5]. Products consist more and more of intangible assets and many steps of the product development process can be performed in the virtual sphere (e.g. simulations). If value creation takes place in the virtual sphere, labor becomes more and more location-independent [6]. The value creation process is cooperative, decentralized and self-organized [7,8]. According to Spur, it is necessary to detach oneself from the factory-focused perspective on the production system [8,9]. Company boundaries are disintegrating, because an increasing amount of cooperation is realized in projects and networks of cross-company stakeholders [10,11]. In order to keep pace with the global development and competition, companies are challenged to open up to these changes. Abilities of knowledge exchange and knowledge management are increasingly determining the competition [12,13]. The concept of interactive value creation - defined as a partnership between customer and producer - copes with the above-mentioned changes [10,14].

The cooperation of autonomous stakeholders in the value creation process produces positive effects of emergence, which generate a higher added value. Effects are emergent if they are not allocable to a single element of the system or the addition of properties of system elements, but rather constitute synergies in an unpredictable, irreducible way [8]. The ability to facilitate stigmergy, to self-organize in an open value creation system, facilitates the utilization of emergence in the process, where decentralized stakeholders are collectively acting in an intelligent way [7,8]. These new patterns of value creation can be observed alongside the whole value creation process. Accordingly, one can speak not only about Open Innovation, but also about Open Production.

Figure 1 shows potential access points for customers. Open Production leads to the utilization of emergence based on a value creation within the production processes, which is characterized by openness [7,8]. Openness "describes the ability for interaction with other elements and is at the same time a prerequisite for the long-term viability of systems" [7,8]. Therefore, Open Production can amplify the net value creation. From an economic perspective, this concept establishes the possibility for individuals to act on the same level as companies in the fields of research and development, production and marketing. In this context the protection of intellectual property is a highly sensitive topic and has to be taken into account [7,8]. Redlich explicitly proposes a so-called granular opening. Granular means that it can be arranged on many different levels and enables companies to open up in a way that is appropriate to their policy [8,15]. Thus, granular opening gives companies the opportunity to increase the overall net value creation, while simultaneously covering competitive knowledge [8]. And in order to compete in a globalized and shifted market they have to use these opportunities [16].

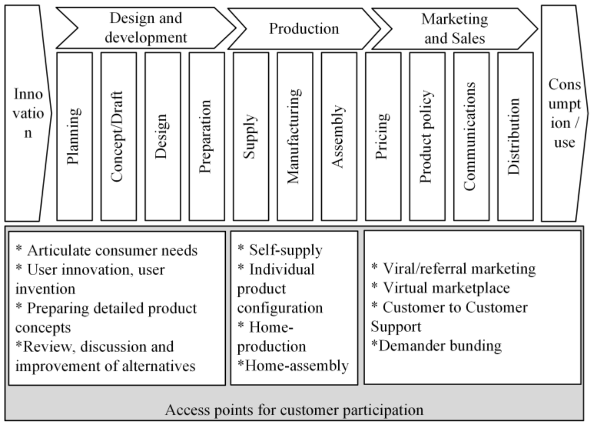

Figure 1: Value creation process: access points for customer participation [17]

In sum, Open Production becomes possible, because first of all the core element of an actual production system is the knowledge about the manufacturing process. Secondly, the technological development of ICTs supports the aggregation and cooperation of many different stakeholders. Thirdly, the technological development in the field of production systems proves this as a matter of fact. Open Source Hardware is one part of the concept of Open Production. (Figure 2) It is based on the premise, that necessary information for the building of factories as well as the manufacturing of parts to produce goods is published so that everybody potentially has access to all information [3,7,8]. Two examples for the new manufacturing methods, which enable micro-factories, are rapid prototyping and square foot manufacturing. Digital Fabricators can be controlled location-independent by a remote control. Thus, they enable to produce highly individualized with a minimal loss of materials [4,7]. Examples for Open Source Hardware in the field of rapid prototyping are RepRap (http://reprap.org/wiki/Main_Page) and Fab@home (http://www.fabathome.org/), which both offer information and knowledge to create digital fabricators [3,4]. Square foot manufacturing is another technological development in the field of production systems, which enables mobile production sites on the basis of a square foot factory (SFF) [18,19]. Square foot manufacturing (SFM) is known as an advancement of desktop manufacturing. In Figure 2 such a micro-factory is illustrated, which creates the possibility to build a small production site.

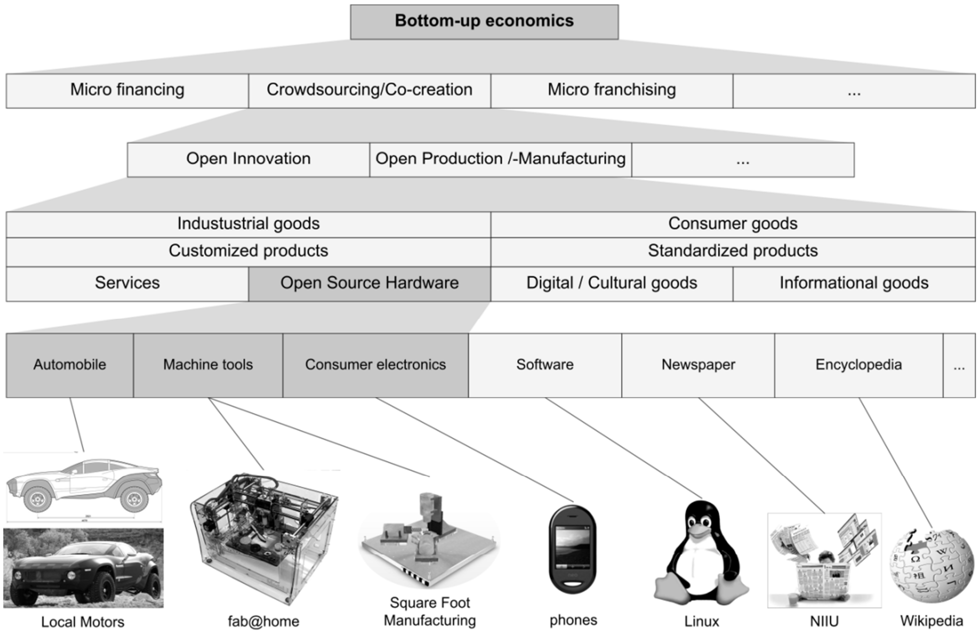

Figure 2: Systematics of the bottom-up-economics [20]

One example for a successful business model, in which the adjustment process in terms of bottom-up-economics based on the new ICTs and manufacturing technologies is mastered, is realized by the company Local Motors (http://www.local-motors.com/). Not only the development of the company´s cars has been realized through the cooperation of customers and producers, Open Source Licenses of construction papers offered the possibility to use the effects of emergence for increasing the net value creation also in the field of production [13,21]. A socially sustainable economy can be realized upon these principles. First, private stakeholders are able to become producers. Second, these producers can interconnect and, thus, develop and produce complex products. Third, based on the development of new business models (e.g. Local Motors) their production becomes profitable and competitively viable [8,17,19]. Consequently, the paradigm shift based on the new ICTs and manufacturing technologies leads to empowered customers and enabled prosumers, which fosters social sustainability. Based on these insights into the bottom-up-economics and Open Production social sustainability and its concrete operationalization will be considered to analyze the chances of the new manufacturing methods in the following section.

3. Open Production and Social Sustainability

3.1 Indicators of social sustainability

Sustainability is an interdisciplinary concept which is related to an enforcement of participatory processes since the Brundtland Bericht in 1987 and the conference of the United Nations in Rio in 1992 [22,23]. The three pillar model, which includes besides the ecological sphere, the economic and social area, reflects a common understanding of sustainability since 1992. Further improvement of this model contains interrelations between the three areas economy, ecology and the social field within an integrated concept of sustainability [24]. Until now social sustainability is not commonly operationalized, different indicators have been proposed. Empacher/Wehling (1999) state as key indicators: basic needs, social resources, equality in chances, participation, security of existence, cultural diversity [25,26]. Some authors recommended an understanding of social sustainability as global social justice in the sense of good working conditions, fair wage and income equality [25,27,28]. Whereas concepts based on Open Production increase the amount of intersections and possibilities to access the value chain, they represent no direct enabler of the other key indicators of social sustainability proposed in the literature (e.g. basic needs, social resources). Thus, as central criteria of social sustainability, ‘participation’ (taking part in processes) and ‘empowerment’ (enable the access, e.g. world market) of the people will be considered below [29,30]. These criteria are highly relevant regarding micro-factories, because Open Production offers more access points to the value creation chain [Figure 1] and therefore increases the possibilities to participate in international value chains and empowers to compete within the global market.

3.2 Towards a collaboration-oriented industrialization

Due to a higher proportion of knowledge in the product, the information and communication technologies and the new manufacturing technologies, stakeholders are *capacitated to participate* in real, global value creation processes, in contrast to the conventional development cooperation practices, which were hitherto driven by companies from the industrial nations. Many decentralized actors have the possibility to connect their local production within the micro-factory to other micro-factories, so that larger production networks can evolve [Figure 3].

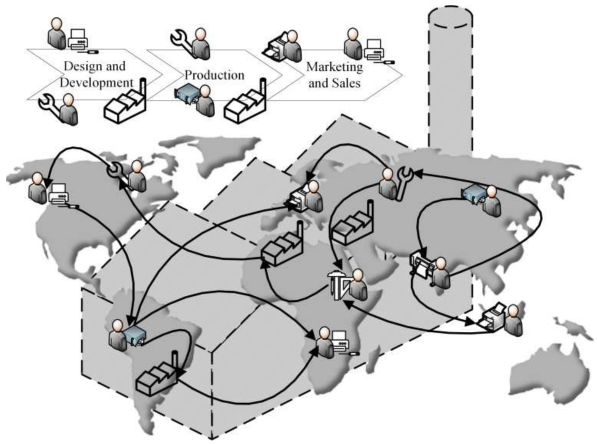

Figure 3: Global manufacturing network of autonomous decentralized micro-factories and companies

Accordingly, from the bottom-up-economics one is able to derive the strategy for a collaboration-oriented industrialization. Import-substituent industrialization and export-oriented industrialization have been applied top-down with the aim of structuring the economy in order to generate growth [31]. *Collaboration-oriented industrialization* aims primarily at supporting collaboration between customers and producers as well as between entrepreneurs and owners of micro-factories.

Whereas cooperation is defined as an interaction, which enables every participant of the cooperation to achieve his own goals [32], collaboration takes place at eye level and is the most intense form of cooperation. Collaboration is characterized by a reciprocal relationship and emphasizes the bidirectional increase of the participants´ potential [33]. It fundamentally characterizes the principles of bottom-up-economics [8]. Mechanisms of cooperation result in an increasing of the total value creation in a way that every participant is able to find himself in a win-win situation [13]. The game theory proved that win-win-situations on the basis of collaboration (even of competitors) are possible with the help of co-opetition, a value creation strategy between competition and cooperation [13,34]. As a result, a capitalistic-oriented market order can evolve and replace the current rent economy that many experts criticize [35]. The problem of recipient countries is that they remain in dependency, even if companies settle in their country, because the population does neither participate in the value creation process as an equal partner nor does it necessarily participate in the distribution of earnings [36]. Collaboration-oriented industrialization supports the evolving bottom-up-economics and is therefore a chance for developing countries to escape the marginality trap [35].

Thus, collaboration-oriented industrialization implicates an opening of the companies' boundaries. From the companies` point of view the financial incentive is that they receive the revenue of increasing their part of the net value creation. Based on the morphology of the design of value creation the different opportunities of companies to give their customers more possibilities to participate can be described within the dimensions of value creation artifact, process and structure as shown in figure 4 [8]. For example, if the modularity of the artifact is increased, more stakeholders have the possibility to participate in the production of the value creation artifact, because the artifact is designed in a way that offers interfaces which are compatible with more products [8].

As a result, the individual profits from Open Production, because cross-national *knowledge transfer* and international business cooperation are supported through the enhancement of opening up the whole value creation process. Hence, individuals get the opportunity to use their increasing customer power [13,20]. The individual attains a higher level of knowledge and economic value as ever before, because of the potential to produce goods networked-based, on site, within their own infrastructure. The stakeholders in developed and developing countries are asked to introduce their specific abilities in an open value creation process. Furthermore, Open Production, e.g. on the basis of micro-factories, can have the potential to *democratize production*. In case of the implementation of Open Source Hard- and Software a democratization of production is the logical consequence [37,38,39,40,41].

Influence Sphere	Possibilites supporting participation and empowerment
value creation artifact	increasing granularity and modularity and generating a co-creation experience enable more actors to participate
	open goods empower anyone to use the hard- or software
value creation process	increasing the width and depth of co-activity, choosing cooperation as competitive strategy and Open Source as business model enable more actors to participate
value creation structure	virtual network, heterarchic organization structure, modular setup, market-oriented inter-organizational coordination enable more actors to participate

Figure 4: Open Production creates participation opportunities

The new patterns of value creation (bottom-up-economics, Open Production) based on the new manufacturing technologies generate chances for social sustainability, because first they empower the people to produce their own goods on their demand and second, the participation of actors, e.g. in developing countries, in the world production is enabled [Figure 5]. Some practical examples already prove the existence of the on-going shift to collaboration-oriented industrialization. Examples in the field of bilateral development cooperation based on FabLabs were chosen which use rapid prototyping techniques for manufacturing. An example for bilateral development cooperation between Germany and Namibia is a FabLab in Windhoek/Namibia, which opened in February 2014 and explicitly "aims to empower local communities […] [and] enhance competitiveness" [42]. Another example is Japan and Bohol/Philippines, where the FabLab should meet the "design needs of some 135 manufacturers under Bohol's creative industry" [43]. Furthermore, a volunteer program is created to develop the knowledge transfer. A third example is the collaboration between Norway and Majiwa/Kenya, where the knowledge transfer is particularly sustained based on a training program [44]. All projects are explicitly implemented to empower the local people and help the local manufacturers to compete within the world market. Participation and empowerment are core elements of this FabLab movement, which was initiated by the MIT. An example for companies, which open their boundaries in order to integrate developing countries and their potential, is the project Lions@frica based on ICTs [45]. In this case, Microsoft offers people in developing countries [temporary limited] access to the software BizSpark and special trainings in order to support local entrepreneurship within this project.

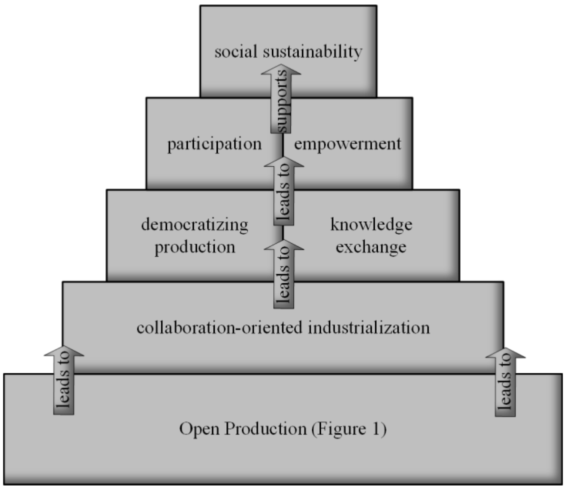

Figure 5: Criteria of social sustainability fostered by Open Production

4. Discussion

This article has shown that the actual paradigm-shift of value creation fosters opportunities for a collaboration-oriented industrialization, which results in a more emancipated form of development cooperation in the long term.

On the one hand, knowledge exchange, democratizing production based on collaborative industrialization build adequate strategies to support social sustainability, but on the other hand there are still problems, which have to be met by an adequate framework and concrete answers regarding the implementation of the new manufacturing methods. Empowerment happens only, if the participants are willing to share their knowledge with their colleagues [39]. The participation of the actors cannot be guaranteed, thus there are many cases known, where participation could only be insufficiently realized [39]. Furthermore, the participation of an individual within an Open Production affords specific qualities and the readiness to assume risk. Yet, democratizing production through the implementation of open source hardware, open source design and open source software is in an early stage of development. The democratizing of production depends on the use of open source soft- and hardware. In this context, the topic of intellectual property needs to be reevaluated, since open source models challenge existing patent and copyrights. This is an important prerequisite in order to find adequate models which fit the underlying mechanisms.

Moreover, other impact factors have to be considered, for example the location, which is chosen for the FabLab, as the Norwegian development institute stated in its development cooperation evaluation [46]. The infrastructure and the associated radius, in which people are reached, are dependent on the chosen location. Self-evidently, the other indicators of social sustainability, which were not taken into account here (economic and ecological sustainability), and, furthermore, the development of adequate business models have to be considered as central requirements for the desired development. Besides, some authors state that 3D-printers are still in an early development stage and, consequently, do not have the reliability, which would approve their implementation in developing countries [4]. To conclude, there are a lot of difficulties, which have to be met. An adequate environment has to be found, business models developed and participation as well as empowerment have to be evolved within a participatory culture of openness to foster the knowledge exchange.

Taking advantage of these opportunities is dependent on the solution of the described problems. In a long-term view Open Production hands the development of a country over to its people, so that the participation and integration of the developing countries is finally possible. Today´s development cooperation has the opportunity to change from a top-down-oriented cooperation, determined by a power elite, to a collaboration-oriented industrialization driven by stakeholders from countries with different development status connected in a global value creation at eye level.

Accordingly, it has been shown that there are highly-relevant chances for social sustainability lying in the new manufacturing technologies. In particular the FabLab movement has to be further observed. Yet, an evaluation of the long-term effects is still missing. The amount of data regarding successful or misleading strategies is often insufficient for further scientific research. Until now, there exist only few studies, which enable scientific researchers to evaluate the implementation of digital fabricating. Thus, further evaluation studies are required to achieve more detailed insights into the mechanisms.

Nevertheless, it can be stated that micro-factories represent a great chance to foster social sustainability in terms of fulfilling democratizing production and knowledge exchange based on collaboration-oriented industrialization. The concept of Open Production is delivering the theoretical framework to categorize and implement these new forms within the value creation structure, process and artifacts. The observed examples show that a slight shift towards collaboration-oriented industrialization is already taking place. Grasping these new phenomena will help to enable sustainability in production and set up controlled strategies to improve sustainability within the production cycle.

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