OpenLabs - Collaborative Industrialisation with Distributed and Open Source Microfactories

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Notes: Open architecture, Manufacturing network, Open Production

Abstract:
Technical progress in production technology, the advancement of ICTs as well as increasing social and economic imbalances and ever-scarce resources ask for new means of value creation. With the spill-over of the highly efficient and innovative open source principles to the world of physical goods and products, new modes of value creation appear that put into question traditional economic strategies and assumptions by stressing collaboration instead of competition, knowledge sharing instead of black box engineering and, thus, fostering the empowerment of the people to participate and get engaged. The here presented multidisciplinary *OpenLabs* concept takes into account these new patterns of value creation based on open source principles and is a suitable approach to increase the overall empowerment and participation in local communities in developing, but also in developed countries.

1) Introduction

The common pursuit for growth leads to developments in industrial and emerging countries that are not sustainable and foster imbalances on the economic, social and ecological level. Forcing economic structural adjustment programs often come along with a loss of resilience of social systems and relations. This results in dependencies and social imbalances as well as a reduced and heteronomous participation of the society in economic and social developments.

Technological progress and the manufacturing of machines and goods - as the fundamental basis for industrialisation and wealth - has been tied to factories and companies for a long time. Consequently, the access has been limited to very few actors. Associated knowledge is under seal (closed source) due to national and international patenting and licensing leading to the fact that a lot of technologies are not available to those in need (e.g. developing countries) [1]. Whereas from an economic perspective, property rights are considered to be an obligatory precondition for the innovative activity of a firm [2], recent scholars on crowd intelligence, open innovation and value co-creation show that individuals who engage in collaborative innovation activities follow motives that lie beyond profit-oriented and monetary incentives [3]. These new patterns of value creation are characterized through networking, collaboration, decentralisation [4] and openness and can be summed up under the notion of bottom-up economics [5]. The range of so-called distributed value creation systems (for tangible, intangible and informational goods) varies from production networks that integrate external actors through Open Innovation, Crowd Sourcing etc., via communities of knowledge creation (e.g. *Wikipedia*), open source software communities (e.g. *Linux*, *Mozilla*, *Android*) to peer2peer-production approaches and open, networked manufacturing workshops (e.g. *FabLabs*, *TechShops*, maker communities). There is one thing that they have in common: They are based on an open source architecture of the value creation artefact and process. As a result, they offer an easier access to existing knowledge [6] and production means [7] and, therefore the possibility of a growing societal participation in the value creation process [8].

These new patterns we can currently observe are a sign for an actual paradigm shift in (industrial) value creation. New models and theories are needed in order to describe and understand current socio-economic transformation processes. Instead of taking the perspective of a single firm respective the user, we are investigating value creation systems that consist of different heterogeneous, distributed autonomous actors that are cooperating in order to commonly create value [9]. This meta-perspective also demands a new understanding of the product or value creation artefact itself. Referring to findings from the service-dominant logic [10], we consider the product as the solution of a common problem (getting from A to B in a certain amount of time) and the provision of a certain functionality and, thus, primarily following the pursuit of substantive instead of profit-oriented objectives.

Whereas there is a lot of literature on the success, the development process [11] and the modes [12] of open source software development, the potentials of open source hardware for new forms of value creation in a sustainable society as well as for new approaches within the field of development cooperation have been overlooked for a long time.

2) From open source software to open source hardware

History of technology revealed a remarkable success of the open source movement. Starting with a few hackers who began working together, these days, open source software communities comprise millions of people who very successfully and jointly develop a wide variety of software and operating systems (e.g. *Linux*, *Mozilla Firefox*, *OpenOffice*). Due to a small number of employees being part of the development process, software companies focusing on proprietary software cannot compete with the innovativeness and responsiveness of mass scale collaboration enabled by open source principles. In many cases, open source software products outreach propriety software in terms of quality and performance [13]. Even more, open source processes and developments are more efficient and adaptable [14].

If that is the case for software development, the upcoming question would be: Are these concepts and principles of open source also applicable to the world of physical products and industrial production. Actually, many cases can be observed where the idea of open source has been successfully transferred to the world of physical products. In this context, *open source hardware (OSH)* describes technical tools or machinery that can be manufactured by construction plans free of license costs. There already exist entire documentations, for instance stock lists, construction plans, source codes and guide books for OSH in different categories such as automotive (e.g. *Local Motors*, *OScar*), computers, agricultural machinery (*Open Source Ecology*), audio devices (*Home-brew D-STAR radio*), drones, machine tools (laser cutter, CNC machines), 3-D printers (*RepRap*, *Fab@home*) and the like. They have been developed as part of different projects and are now freely available. The obtainable quantity of such technologies is very likely to reach a critical mass soon, which will lower the entrance barrier of their utilisation to a point, where a large number of societal groups may benefit from them.

Many projects and developments prove that, with the help of open source principles, major technological advancements not necessarily have to be initiated by profit driven private companies. The *RepRap* project is a prominent example of how open source can enable and boost product development. The idea of the *RepRap* project was to jointly develop a free accessible and cheap 3D-printer within a community [15]. Nowadays, there is a complete set of documentations and instructions online accessible. By buying a set of standard parts, anyone is able to build his own 3D-printer. At the same time, new business models have evolved from the project, e.g. building kits and ready-to-use printers. Finally, *Makerbot Industries* was set up and within 3 years sold 22,000 3D-printers based on the *RepRap* model [16].

Moreover, new value creation patterns and business models considering aspects of open source can also be found in traditional industrial production, e.g. *Tesla Motors* [17], *Toyota* [18], who opened up (parts of) their IP portfolios for free usage. Another glaring example for new methods within a highly competitive and traditional industry like the automotive can be observed with the US-based company *Local Motors* that managed to bring a car to production with the use of open source-principles by means of a collaborative internet platform together with an internet community within 2 years. In addition, the development costs of the street-legal off-road car named *Rally Fighter* were only a fraction compared to those of other car manufacturers. The documentation of the products are open source and accessible by anyone. The final assembly of the products is carried out in so-called microfactories throughout the US either by the customer himself or by the employed mechanics [19].

Open Source Ecology (OSE) is another successful open source project that focuses on sustainable development [20]. With the so-called *Global Village Construction Set* a group of 50 machines was identified for carrying out fundamental tasks like cultivation, housing, mobility and production of goods. These should enable people all over the world to live more autonomously and independent from markets and scarce resources. The documentation of the machines is online and freely accessible. The development is still going on, but many products can already be built, e.g. laser cutter, tractor and kiln [21].

Not only for the OSE project, but also for other OSH developments the basic principle has been the application of the *open source appropriate technology (OSAT)* concept. The idea behind this concept is to develop and design products for sustainable development in a very simple and modular way in the spirit of the open source movement [1]. Users around the world voluntarily collaborate to create a library of freely accessible documentation of products that can be easily and with minimal skills rebuilt by local communities that have access to a basic set of production technology and resources.

3) Potentials of new value creation patterns – replacing competition through collaboration

OSATs and their collaborative distributed development bear many potentials in the social and environmental as well as the technological realm [1]. They help to bring back manufacturing and value creation to the people and democratize product design and manufacturing and, thus, foster a more sustainable and human-centred instead of profit-oriented design. Moreover, people can react to the often criticized human estrangement from value creating activities that is a by-product of the industrial change and its focus on specialisation, centralisation and mass production. Debates and discourses within the realm of international development cooperation also agree upon the fact that a sustainable development can only be achieved if potentials on the individual and societal level are made available by empowering the people to participate. In order to do so, access to those critical information for a sustainable development needs to be provided.

However, these socio-economic benefits require a rethinking of (industrial) value creation and related economic activities. Not only the concept of "factories" as a symbol for the age of industrialisation has to be put into question, but also the predominant assumption that a patent system stimulates the innovative activities of single firms. According to an analysis by Boldrin and Levine the contrary is the case. They were able to show that giving the opportunity to profit from the competitive profits of others without establishing own innovative products on the sales market, the basic interest in investing in research and development decreases [22]. Moreover, it is assumed that the innovative ability of firms is limited in comparison to the innovative ability of the crowd that engages in the collaborative development of open source technologies due to the integration of very heterogeneous perspectives on a common problem [23]. Given the example of *Local Motors*, it is possible to already empirically prove that due to flat hierarchies and a low level of bureaucratisation new ideas can be realised within a few months, whereas it is taking years and can costs billion to realise them in conventional corporations such as *Volkswagen*. Additionally, costs for development, human resources, logistics, procurement, administration and real estate are lower, which also lowers the entrance barriers for entrepreneurs to realise new ideas. Efficiency, by definition, is a measurable concept in order to quantitatively determine the ratio of output to input. However, different indicators can be applied in order to do so. Longing for efficiency of manufacturing technologies means for instance: Maximizing energy and cost efficiency as well as productive efficiency. However, these definition usually rely on strictly economic rationales.

According to Thomson and Jakubowski, an "open source economy" is also one that is maximally efficient, however, efficiency in that case refers to "the capacity for putting innovation in the greatest number of hands" by enabling producers with any level of capital resources to participate [21]. In the following chapter, a concept for the realisation of a sustainable development through the establishment of distributed open source microfactories is introduced that relies on the idea of Fab Labs developed by the MIT as well as the Open Source Ecology and integrates them in a broader multidisciplinary concept [24].

4) *OpenLabs* – Democratizing value creation!

OpenLabs can be understood as community-operated, self-organizing and open manufacturing spaces with an easy access to robust, easy-to-handle production means and the promotion of their utilisation. They provide open workshops and a space for encountering, learning, experimenting, joint creativity and value creation that is free of hierarchy.

The essential technical requirement of *OpenLabs* is the replicability of the manufacturing space and its resources (see Fig. 1). In this way, with the attainment of a critical mass, new open manufacturing spaces may emerge. Technological innovations of the last decade constitute the technical basis of the *OpenLabs* concept.

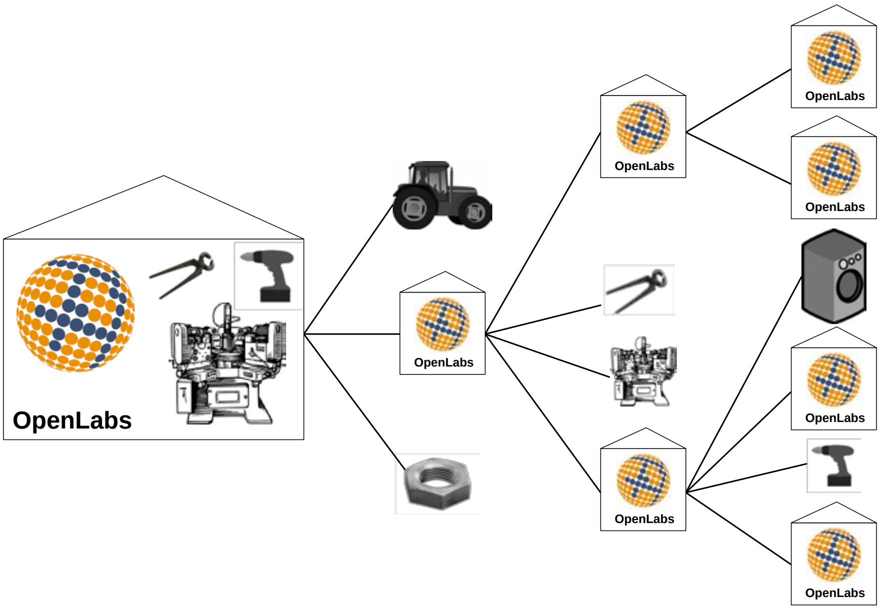

FIG 1: *OpenLabs* as self-replicating systems

These are, first of all, the development of robust, modular and self-replicable machine tools which are easy to manage/use [25]; secondly, the development and availability of open source construction software and operating systems [26], and thirdly, the proceeding development of OSH [27] as well as the development of the Fab concept [24].

Furthermore, a theory of small machine tools sets the basis for a modular and small size machine development approach [28]. The technological advancement of small machine tools [29], a corresponding modularity concept [30] as well as suitable interfaces [31] support and facilitate the idea of open source hardware.

Another pivotal feature of the *OpenLabs* concept is the regional and global networking in respect to organizing as well as information and communication technology. On a micro-level, real self-organized manufacturing spaces can be created, which are embedded in the local socio-economic structures (e.g. agriculture, production of energy, irrigation systems, manufacturing of artefacts, utilizing resources, education infrastructure). They must be adjusted to the everyday reality of their users just as much as to the obtainable local resources in order to secure viability and acceptance as well as to initiate new business models. On the meso- and macro-level the respective manufacturing sites need to be embedded in an existing, worldwide network. The subsequent formation of communities of practice consisting of globally distributed individuals that integrate creativity, cooperation and specific knowledge to the development and manufacturing processes or solve problems during the implementation period have to be supported. They need assistance to such a degree that the actors do not only share their knowledge and experiences most ideally, but also to ensure the availability for inexperienced users (e.g. knowledge platforms, wikis)

Target groups are first and foremost people, which due to a lack of specific education, a lack of financial resources, lacking infrastructure and/or geographical distance have been denied access to such technologies so far. Thus, the third pillar of the *OpenLabs* concept is an educational coaching concept accompanying the implementation in order to foster the maturity of the users, gain a technological literacy that goes beyond mere theoretical knowledge in terms of an actual capacity building. Following the everyday reality of respective learners, knowledge needs to be built "bottom-up" in problem oriented teach-and-learn-arrangements connected to their respective experience realm (e.g. manufacturing of a service part for an automobile).

According to the pillars networking, manufacturing and education the realisation of the *OpenLabs* concept enables:

- Increased participation in the creation of value (open access to production means, resources and know-how)
- Reduced usage of resources (via utilisation of recycled and locally obtainable materials as well as a reduction of transport costs through local production)
- Bottom-up developed, user-centred frugal innovations
- Independent, self-organized and collaboration-oriented development on a micro-level
- Inclusion of local sites in a global network of value creation and knowledge

5) Design principles and requirements for open production and *OpenLabs*

However, these new promising phenomena cannot be described with traditional economic perspectives on value creation. In these terms, openness becomes a critical system prerequisite in the new era of value creation. Openness has many facets and can be operationalized in many ways and also its range of intensity varies. In order to describe this paradigm shift towards an open value creation, but also to outline the inherent design principles and requirements for setting up *OpenLabs*, the authors use a value creation taxonomy that is constituted by the value creation system that comprises of structures, processes, and the subject of value creation (i.e. the value creation artefact) [9]. By comparing the characteristics of traditional industrial mass production with the concept of open production, we want to point out that (as in the case of OSATs and *OpenLabs*) those two perspectives are diametrically opposed (see Fig. 2).

Criteria of Value Creation Systematics		Industrial Mass Production	Open Production
Value Creation Artefact	**Complexity**	**High**	**Low**
	Property Rights	**Closed**	**Open**
	Functionality	**Mono**	**Multi**
	Modularity	**Monolitic**	**High**
	Ease to Use	**Low**	**High**
Value Creation Process	**Co-Activity**	**Coordination**	**Collaboration**
	Competitive Strategy	**Competition**	**Coopetition**
	Business Modell	**Closed Source**	**Open Source**
Value Creation System Structure	**Connectivity**	**Bilateral**	**Linked to Network**
	Organization	**Hierarchical**	**Adhocratic**
	Communication	**Low**	**Participatory**
	Role Dynamics	**Static**	**Dynamic**

FIG 2: Industrial vs. Open Production

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Thus, the set-up of recent and future value creation systems is completely different from a traditional value creation system. Prevailing features are collaboration, empowerment, decentralisation, modularisation, self-replication, knowledge sharing and transfer, open source principles, etc.

Focussing on the production systems themselves (on the level of a single *OpenLabs* microfactory), rather different characteristics compared to modern high-tech production are crucial to its success. Those entail:

- Robustness, wear-resistance
- Minimal capital and operating costs
- Low precision
- Flexibility and adaptability
- Standardized machine parts and products
- Basic raw materials
- Small spaces and high movability

Furthermore, the composition of a sustainable and holistic concept of decentralized and interconnected open manufacturing spaces is not a task which can be solved by engineers and technicians. Instead, the socio-political and socio-economical parameters have to be analysed and evaluated beforehand which calls for an inter- and transdisciplinary research approach.

6) Summary and implications for future research

Technical progress in production technology, the advancement of ICTs as well as increasing social and economic imbalance and ever-scarce resource ask for new means of value creation especially with focus of sustainable economic concepts. It has been shown that the open source movement spilled over to the world of physical goods and products and that the principles of open source deliver a new way of value creation which empowers people all over the world to participate in value creation processes. Thus, efficiency needs to be redefined in a more holistic view: The more people that participate and collaborate on innovation, the more people benefit from it. The *OpenLabs* concept was presented in order to describe a model which takes into account these new patterns of value creation based on open source principles as we think it is a suitable approach to increase overall empowerment and participation in local communities in developing, but also in developed countries. Furthermore, requirements and design principles for the set-up of the *OpenLabs* concept were outlined.

However, it became clear that there are many questions unanswered with regard to open source hardware. New business models and value creation concepts are necessary to fully understand, describe and, in the end, to harness these new phenomena. New machine concepts and production technologies that are different from the high-tech industry standards have to be developed.

We don’t know yet if the story of OSH will be a game changer as it was in the case of open source software. How will traditional industry face these new challenges? Will they be agile enough to adapt their business model and, thus, stay innovative? How will developing countries evolve with the access to means of empowerment and independence? These are just some of the questions, and only a few can be addressed by research. However, we are given great opportunities to deeply influence the world and research has to find its role in that process.

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