

The role of Open Source Hardware in harnessing User Entrepreneurship in developing countries

Economics: Harnessing Entrepreneurship and business opportunities for positive impact

Remo Giovanni Abbondandolo

Bocconi University, Italy

Piazza Mercato 10, 83040
Flumeri (AV) ITALY
Phone: +39-333-4925605
Fax: +39-0825-0999014
e-mail: remo.a@studbocconi.it

Notes on the author

Remo Giovanni Abbondandolo is a final year Master of Science student of “*Economics and Management of Innovation and Technology*” at Bocconi University-Double Degree with the program “*Management of Innovation and Business Development*” at Copenhagen Business School. He holds a Bachelor Degree in “*Economics of International Markets and New Technologies*” from Bocconi University; he studied also at Fudan University (China), University of Illinois at Urbana Champaign (USA) and Chinese University of Hong Kong. He has won scholarships for his studies and he has been participating in several international Business Case Competitions. He has also work experience in Denmark, India and Italy.

The role of Open Source Hardware in harnessing User Entrepreneurship in developing countries

Economics: Harnessing Entrepreneurship and business opportunities for positive impact

Remo Giovanni Abbondandolo

Bocconi University, Italy

e-mail: remo.a@studbocconi.it

Abstract–The aim of this paper is to analyze the entrepreneurial opportunities presented by the emerging phenomenon of Open Source Hardware (OSH) to users in developing countries. In this context, it is discussed the role played by Arduino (www.arduino.cc), the first and most successful OSH platform. One of the peculiarities of Arduino is that it stimulates entrepreneurship from the users' side. In fact, thanks to this new concept, users have tools to develop their own products at reasonable costs and eventually commercialize them at a lower price. Indeed, several companies run by Arduino users made not only non-marketed products, but also goods embedding existing technology at a lower price. The analysis of empirical cases was conducted gathering information through personal interviews with Arduino founder and with successful user's entrepreneurs, using data also from OSH communities. The study has proved that OSH has a dual effect on Developing Countries: on the one hand, it harness entrepreneurial opportunities that require low initial investments; on the other hand, products and services of new ventures are more accessible to small communities in certain regions. This in turn leads to recommendations to potential entrepreneurs and policy makers, who can adopt policies in support of entrepreneurial activities.

Introduction

Recent research into the source of innovation activity has shown that users are one of the most precious external resources in New Product Development (NPD) process, or simply for the improvement of an existing product (Franke, von Hippel and Schreier 2006; Baldwin, Hienert and von Hippel 2006).

As a matter of fact, users are very helpful when they experience a certain problem (e.g. the invention of car seat for low birth weight babies by *Angel Guard*) or simply when they are not satisfied with an existing solution and they want something that fits their needs (e.g. the creation of new extreme sport industries like kite surfing by *Bruno* and *Dominique Legaigoux*).

Hence, companies recognize that valuable ideas are coming also outside firm boundaries, thus they are moving toward to a more "open approach" (Chesbrough, 2003), focussing also on new form of collaborative innovation (Prandelli, Sawhney and Verona 2008). However, new studies have also shown that users stop sharing their innovations for free, in order to start to commercialize them; subsequently they become entrepreneurs with the commercialization of their products (Hienert 2005; Shah and Tripsas 2008).

This phenomenon was enhanced by the diffusion of Internet, in particular with the spreading of online communities (Franke and Shah 2003; Jeppesen and Frederiksen 2006) and the massive presence of toolkits for User Innovation freely available online (Franke and Schreier 2002; Katz and von Hippel 2002), through which users are supported to become entrepreneurs. More importantly, it is the *Open Source* model that allows users-who work mainly in a community- to increase the pace of innovation by exploiting their entrepreneurial attitudes.

This is demonstrable primary in problem solving situations, where users are more willing to innovate and to find a solution that fits exactly their needs. Even so, there is not a unique solution when it comes to users dealing with a certain problem. In fact, an open approach gives voice to anyone who wishes to change and modify for free certain software, which may increase the likelihood and the portfolio of solutions, as well as new products and services.

Even though the term Open Source was initially referred to Open Source Software (OSS), in the last five years it is noticeable the change of technology also in the open environment, with the increasing phenomenon of Open Source Hardware (OSH). In that case, the information is additionally open to everyone to access easily and for free online, but it is the hardware-a tangible good- that has been opened, hence it needs to be physically produced before using it.

Despite the extensive academic research on user innovativeness also in the OSS field, the literature does not contain a parsimonious construct that can be validating for analyzing OSH opportunities for users innovators who eventually become entrepreneurs. To explain this phenomenon, it will be discussed the role played by Arduino (www.arduino.cc), the first OSH platform. Thanks to the OSH concept, users have the tools to develop their own products at reasonable costs and commercialize them at a lower price, without asking for any permission from Arduino owners and paying any royalties to them (apart from the use of Arduino brand). Therefore, several outlandish companies run by Arduino users made not only products which are not yet commercialized, but also goods embedding existing technology at a lower price. In this way, Arduino harness user entrepreneurship.

This is particularly relevant for developing countries, where the result is twofold. Firstly, people through Arduino can seek for new business opportunities and start new ventures with low initial investments; secondly new start up may produce also goods that replicate the commercial ones, reducing dramatically their cost of production without paying any property rights, which bring down the final price, thus bumping up the accessibility of some basic products that is quite low in developing countries.

The paper is organized as follows. First, there is a brief introduction of the concept of user entrepreneurship and OSH. Then, the illustration of the Arduino case and its impact on the market side, in particular on user entrepreneurship, with the description of new ventures based on Arduino concept. Next, the main findings of the empirical analysis are shown, by explaining the business opportunities presented in developing countries. Thereafter, recommendations are provided to users with entrepreneurial attitudes, and also to policy makers, who can adopt new policies in order to support entrepreneurial activities in a certain country or in a particular strategic industry. Finally, future research is encouraged in order to cover some gap and limitation of this study.

Literature review

In the last decade, new form of collaborative innovation has received a lot of scholar attention, given also the relevance of the phenomenon in business contexts. What it is new and not fully investigated is the OSH technology and the resulting step that allows users to switch their status from innovator to entrepreneur, about which a brief overview of these two main streams of theories is reported.

User Entrepreneurship

According to conventional wisdom, users freely reveal their know-how and active collaborate with organizations in NPD; in fact users' benefits are given by their personal use of the resulting innovation, and not from selling it (von Hippel 2005). Consequently, companies are focusing on methodologies for harnessing users' creative potential (i.e. Lead-User Method) and methodologies to identify and evaluate users' idea (i.e. Broadcasting, Collaborative Filtering and Pyramiding). Notwithstanding that, new studies showed the emerging phenomenon of users that start to commercialize their innovation and then become entrepreneurs (Shah and Tripsas 2008). This new theory has shown some contrast with the classic model of the entrepreneurial process: end-user entrepreneurs are distinct from other types of entrepreneurs, given that they have personal experience with a product or service and derive not only financial benefit from commercialization, but also through use.

In the table below there is a summary of the main successful cases of individual or group of individuals who develop new ventures. The main characteristic of these examples is the problem-solving aspect: users had experience of a certain problem or want to make something new; hence they decide to create their own business.

Tab 1. Examples of User Entrepreneurs.

Innovation	User innovator-entrepreneur	Description
------------	-----------------------------	-------------

Juvenile products industry	Parents. Example of companies founded: ABC Fun Pads, Baby Einstein (Shah and Tripsas 2008)	84% of juvenile products firms in the US founded in the last 20 years were founded by users-innovators
Snowboard	Jake Burton	Skiing enthusiast who got bored by traditional skiing. He became snowboard pioneer and founder of BURTON Snowboards
Skateboard	Tony Alva	He is one of the most influent skateboarder of the world, who founded ALVA Skateboard
Kite surfing (new industry)	Bruno and Dominique Legaignoux	They were sailors who became interested in Kites when they tried to develop an efficient sailing boat under the brand "Wipika" (1997)
Rodeo kayak (new industry)	(Hienerth 2005)	Due to the characteristics of these two extreme sports (i.e. several unexpected inconvenient while playing these sports) the required level of innovation is high
Mountain Bike	Gary Fisher (von Hippel et al. 2005)	Passion for biking off-road, need for a bike that suited his high requirements. Founded his own firm www.fisherbike.com
Personal Computer	Ed Roberts	Engineer; developer of ALTAIR 8800: the first Personal Computer
Yahoo!	David Filo and Jerry Yang	Stanford PhD candidates, transformed their hobby in a global business
Facebook	Mark Zuckerberg	He was a social network platform user, as well as a user of printed copies of "face books"
Music editing	Propellerhead software, an online community (Frederiksen, forthcoming)	Users originally created complements for other reasons, and then realized over time that there was a business opportunity in it

Open Source Hardware

Until recent years, the term open source was mainly referred to OSS, where the source code is under a license that ensures that derivative works will also be available as source code, protects certain rights of the original authors, and prohibits restrictions on how the software can be used or who can use it. In that context, anyone can use the code provided for free to work on it, with the permission to produce an own version, to make alterations and improvements on the existing code. Thus, the new opportunities presented by the web increase information richness on internet, where people can find other peers in the world that can experience a similar problem, or work on some projects in order to provide a better and cheaper solution for anyone, promoting also innovation from the users' side (von Krogh, 2003). This has caused a big effect on the market, putting in competition the OSS with the commercial software (i.e. Open Office available for free vs. Microsoft Office).

OSH, instead, indicates that the interface of the hardware is explicitly made public, so that it can be used freely. Moreover, the design is also made public, so that others can implement it and learn from it, along with the tools used to create the design. Although OSH shows some similarities with OSS (e.g. users operate in a network that helps to do exactly what they want, they can freely benefit and share it online with communities), there are some important difference that need to be analyzed. First of all, hardware cannot be duplicated without the physical production; subsequently there is rivalry in the consumption. Thus, given the costs that someone has to afford in order to physically produce the good, there is an increasing of commercialization of products, and the consequent risk for running these innovative activates.

Therefore, in this context users become often innovators with a small amount of investments required: they have the tools to develop what they want and share the innovation with peers online, discussing with online communities' improvements and suggestions. In that sense, OSH is interrelated to user entrepreneurship.

Methodology

Overview

For the purpose of this research, the analysis was merely qualitative based on case studies (Yin, 1994). In fact, in this context, it is the best suitable alternative, given that the aim is to provide an explanation about how OSH may foster user entrepreneurship, particularly in developing countries. In addition, case studies are more appropriate for studying contemporary phenomenon in a real-life context.

The analysis was conducted in two separate steps. First, Arduino was analyzed, because of its uniqueness and rarity in OSH context. In fact, the two concepts are working together: Arduino is a part of OSH; at the same time OSH was developed thanks to Arduino. Second, an investigation among Arduino users-who developed new projects-was conducted using multiple case studies approach: in order to check consistency of any similar results or contrasting outcomes for predictable reasons.

The information was gathered through personal interviews with *Massimo Banzi*, Arduino co-founder, and with some users who are running business on Arduino projects: *Nathan Seidle* from *Sparkfun* and *Chris Anderson*, *Do It Yourself (DIY) Drones*. Finally, the analysis was supported also by information from OSH communities.

The case of Arduino

OSH has some similarities with OSS also in this origin. Linux, the most important OSS example, started from users' dissatisfaction of dealing/working with a close and expensive Operating System. Arduino had a similar story. In 2005 *Massimo Banzi* was a teacher at the Italian high tech design school in Ivrea, and he started receiving several and frequent complaints from his students that could not find an inexpensive, powerful microcontroller to drive their arty robotic projects.

The need of his students led *Banzi* to discuss the problem with *David Cuartielles*, a Spanish microchip engineer who was a visiting researcher at the school, and thanks to the help of the Danish student *David Mellis*, the three were able to create the board and the programming language in five days. That is how Arduino, a simple microcontroller platform, was created and designed with the aim to introduce non-hardware and non-software types to embedded devices and give them opportunities for creating interaction designs. Subsequently, the Arduino team decided to put the schematics online, freely available to anyone, hence they create the first example of OSH.

The project started with 3,000 euro for the productions of 200 copies, with the concern of selling them, given that *Banzi's* school bought only 50 pieces. Nevertheless, after few months they realized that several hobbyist and geeks showed interest on this project, thus the team started to think to build a business on it, focusing the entire strategy on the open source design: "*they would copy you in any case*"-said *Banzi*, "*hence we decide to keep it open using a Creative Commons license called Attribution-Share alike, giving anyone the opportunity to modify and release new version of the hardware*". Under the Creative Commons license, anyone is allowed to produce copies of the board, to redesign it, or even to sell boards that copy the design, without the need to pay a license fee to the Arduino team or even to ask for permission.

The only piece of intellectual property the team protect is the name Arduino, which is trademarked and it is the main asset of the company. In fact, in order to make sure that the brand name is not negatively influenced by low quality copies, anyone who is willing to sell boards using that name has to pay a small fee to Arduino.

The basic version of the board costs around 26 dollars, and can be purchased from hobbyist electronics websites. In particular, the company highlights that the boards are "made in Italy", thus not using cheap labour work and low quality materials.

The success of Arduino is obvious. From the 200 first boards sold in 2005, 5,000 Arduino board were built around the world a year later. 30,000 in 2007, and more than 150,000 by the first quarter of 2010. With this trend, the first 1,000,000 boards would be easily sold by the near future. In addition, in December 2010, "*Il sole 24 Ore*", the Italian economics newspaper (corresponding to the British "Financial Times") featured Arduino in its list of the ten innovation of the decade, along with Apple, Facebook, Google and Wikipedia. The newspaper is also promoting an online survey asking people to vote for the most innovative product among that list. Up to January, 9th 2011, 23% of the Italians believe that the best innovation of the last 10 years was made by *Banzi& Co*, ranking Arduino at the second place.

Overall, the success of Arduino is mainly based on the toolkits for user innovation (everyone can modify the hardware), by the trial and error learning approach (design through prototyping), the easiness of the design (no need for a factory to create the hardware) and Instructables (in the website there is every step of the invention). In a nutshell: open approach, brand and community.

Arduino user entrepreneurs' projects

Geeks and anyone interested in programming and in interaction designs become immediately attracted by Arduino. The same was true among students, who can develop their own projects at a reasonable cost, but anyone in general can foster their creativity with Arduino. “*You do not need to be an engineer to do it*”, said *Banzi*, who hold a degree in Engineering. “*Anyone can open, modify, and change the hardware with the tools all freely available online*”. That is how people start to develop odd products, which allow them to interact with the environment. The lists of projects running by Arduino users is comprehensive, but not always those projects are translated in real commercialized products.

After a screening among the most innovative and useful projects, some were selected and reported below. The selection was based considering the innovativeness of the products, the usefulness and the size of the business in terms of revenues.

Tab 2. Arduino-based projects: case studies.

Project	Description
Botanicalls <i>Four graduate students at NY university</i>	New venture that developed a product with the aim to create a way for plants to interact with humans. They made Botanicalls for two main reasons. Firstly, to keep plants alive by translating the communication protocols of the plants (e.g. leaf habit) to more common human communication protocols (e.g. voice phone calls); secondly, to make a connection between people and plants by exploring and visualizing human emotions connection to plants and the ways plants help people. That is especially relevant for people who are unsure of their ability to effectively care for growing things, since they are given visual and aural clues using common human methods of communication.
DIY Drones <i>Chris Anderson, Wired editor in chief</i>	The website is focuses on non-commercial projects by amateurs, who want to either make or buy assembled Unmanned Aerial Vehicles (UAVs). The mission of DIY Drones is to provide cheap products to amateurs- mainly scholars- who cannot afford high prices and cannot find products that fit exactly to their needs. In addition, the company wants to create a simple product in order to diffuse the UAV culture and they want to emphasise the participatory aspect. In fact, what is relevant in this case is the strength of the community. “ <i>The success of this 1 million dollar company is made by three main elements: community, brand, and technology,</i> ” said the founder, <i>Chris Anderson</i> .
Adafruit , <i>Limor Fried</i>	Provides users who have limited time or skills with a wide range of kits and small projects that meet the needs of electronics beginner. They make and sell OSH ranging from the Arduino board to devices Fried designs herself.
Sparkfun, <i>Nathan Seidle</i>	This story has several things in common with Arduino. While working on a class project, Nathan realized how difficult it was for the individual to get the parts necessary to make an electronics prototype come to life. The goal of the company is to get their hands on current technology and information and pass it on to users. They set out to make finding the parts and information that geeks need easier, more intuitive, and affordable so everyone can create awesome projects.
RepRap, <i>Adrian Bowyer-</i> and <i>MakerBot,</i> <i>Bre Pettis</i>	Free desktop 3D printer capable of printing plastic objects. Since many parts of the printer are made from plastic, it is a self-replicating machine , from which it is possible to print for free useful stuff . In this way, it is possible to make printers freely available for the benefit of everyone, especially in communities of developing countries. This product is slightly changing the classical manufacturing processes: the inventor believes that in the future we can print any physical projects for free at home, e.g. a mobile phone or a MP3 player.

Oswash, <i>Jean-Noël Montagné</i>	An example of open source washing machine project which aims to “ <i>rethink the way we wash clothes around the world</i> ”, in accordance with economical, sociological, cultural and environmental aspects giving an alternative to most of the people in the world who currently wash clothes by hand due to the lack of resources.
Solar Power Application (<i>Wolfe 2009</i>)	An Open-Source Monitoring System for Remote Solar Power Applications that deal with the reduction of production costs, using open platforms to make solar monitoring available in developing countries where both the resources and general knowledge are particularly scarce.
PH Probe	An ongoing project that aims to make laboratory tools that replicate the commercial ones for a reasonable price. In particular, in Latin America a PH probe is now under development, using Arduino as heart of the projects.

Findings

The Arduino projects listed are only a small part of the ones currently available. More interestingly, OSH projects in general increase at an exponential rate, and the expectations for the future are increasingly positive (see figure below).

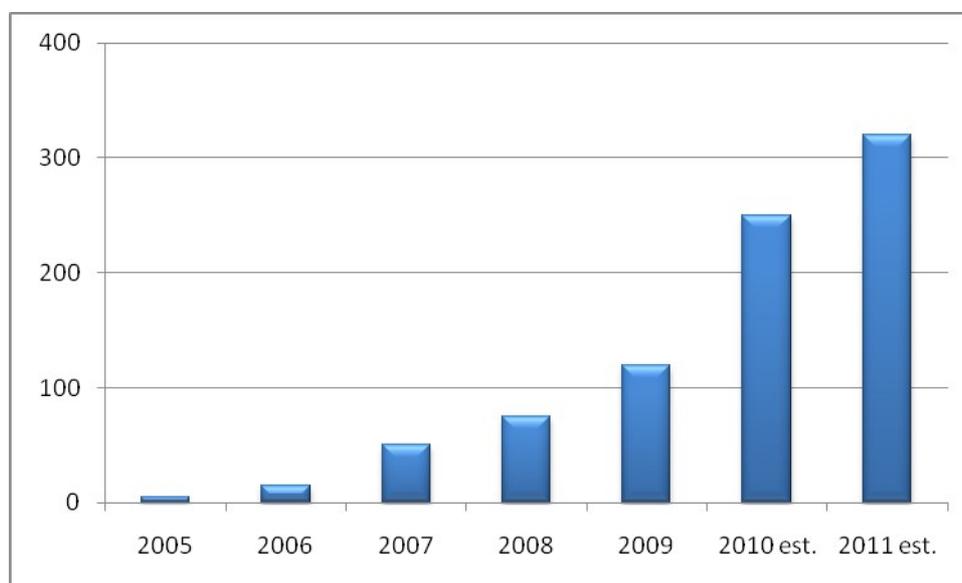


Fig 1. OSH projects. Source: OSHW annual - Torrone, MAKE magazine

Several takeouts are coming from the analysis of the case illustrated.

On the one hand, it increases entrepreneurial opportunities that require low investments.

For example Arduino started with a 3,000 euro as initial investment. It is now the leading platform in OSH with 150,000 boards sold. An additional support of this is given by *Sparkfun*, which has about 20 million dollars revenues company by 2010 and gives jobs to more than 100 employees.

Users with entrepreneurial attitudes have all the tools to develop the products, and the key support of communities, where users give feedback about technical features, how to improve existing products, and in this context serves also as a first market test, to see exactly if there is a market for the product. The business opportunities are also enhanced by the low initial investments required, so there is no need for users to seek microcredit opportunities, venture capitals or business angels as in case of normal start up, which represent crucial limitations especially in developing countries where the financial presents some market failure.

Therefore, even a single user may finance their own project: the Arduino board is really affordable, given that the main cost is represented by the time that needs to be dedicated in prototyping and developing activities, and a website like *Sparkfun* sometimes launches promotion offering good discounts to new customers, with the aim to educate people on the basics of OSH that can eventually help them to become entrepreneurs.

The analysis of the cases has also shown additional entrepreneurial projects. For example, *Oswash* allows individuals to develop and commercial OSH washing machines. There is unquestionably a

market in that since most of the people in the world who currently wash clothes by hand due to the lack of sanitation, water or energy, but they cannot afford a commercial washing machine.

The same can be considered for the *solar power application*, to provide a cheap and alternative source of energy to countries that do not have resources to invest in green or low consumption technologies, given that they have to cope with other big problems.

In addition, laboratory tools in developing countries represent also another business opportunity that can foster entrepreneurship: currently, in Brazil it is under development a PH Probe.

On the other hand, products and services of new ventures are more accessible to small communities in certain regions. In fact, the cases have shown how the price of certain commercialize products dramatically decrease in situations where OSH is applied. 3D printers, for example, are already available in the market for about 30,000 dollars, but thanks to OSH it is even possible to produce a new one for 500 dollars, subsequently it is more accessible even to individuals and institutions in communities in developing countries that can use it to make products.

Furthermore, some of the projects deliver outlandish gadgets, just used by a limited amount of people. Others, however, solve concrete problems and get attention to a considerable audience. Botanically, for example, allows some people in the world to solve a particular problem that they experience (the need to monitor plant while they are not at home), that any company would not solve due to the small catchment area and the high investment required. *“Even if there are 10-15 people in the world that are interested in a certain application, thanks to the increasing of web accessibility we can find them”* said Nathan Seidle, the *Sparkfun* founder.

Conclusions

In this paper, two emerging phenomena were illustrated: user entrepreneurship and OSH, highlighting how the mutual combination can create new business opportunities for single users.

The main results for developing countries are twofold. On the one hand, OSH harness entrepreneurial opportunities; on the other hand, products and services of new ventures are more accessible, and the expectations for the future are increasingly positive. In particular, OSH the industry is developing radically. The figures discussed showed how many users in the world bought and Arduino board. Moreover, also the number of OSH projects is considerable. At the first quarter of 2010, thirteen companies that run OSH projects represent about 50 million dollars. Overall, there are 200 OSH projects, with the expectation of this number increasing by 50% in 2011. In addition, most of the 1 million companies are rapidly approaching 5 million. Most importantly, the estimation made by *Adafruit* about these business models said that by 2015 OSH would likely be a one billion dollar industry.

In addition, as for OSS, developing countries have to use OSH as a way to gain knowledge about the technology itself and as a way of creating technology products that fit their specific needs.

Moreover, combining free software-along with hardware- tools with the technical workforce available in developing countries can enable technology transfer. Consequently, also the literacy rate can be increased: the tools are available online for free, thus the average class of the population who has access to first degree of studies may extend their knowledge. However, one of the main challenges here for developing nations is the expertise needed in using OSH products because they contain a fair amount of innovation. Nevertheless, a combination of institutional vision, qualified personnel, and strong links to user communities may beat these issues.

Finally, the results may help policy makers and NGOs, who can adopt new policies in order to support entrepreneurial activities in certain countries or in a particular industry. Notwithstanding, the success of OSH is also related to a national ICT governmental policy, hence government has a leading role in the economy and in setting up markets conditions.

Few limitations of this study -along with questions for future research- should be noted.

To begin with, in the present paper it was not considered the digital divide and censures that a country like China has to cope with. Some developing countries are trying to build infrastructures and give incentives to households to establish internet connections. However there is still a consistent number of people who have no or limited access to the web.

In addition, language barriers are a factor that can obstruct OSH promotion, where English is the only language used.

Furthermore, for the future the threat of legal controversial that might be raised by big multinationals that are losing bargaining power cannot be excluded. There are no legal infringements that deserve any punishment; however big multinationals can afford big legal proceedings with the aim to discourage OSH where the property rights protection in this contest is very low.

Lastly, it would be recommended to investigate the way users become profit oriented entrepreneurs, analyzing the intrinsic reasons beyond that force users to build a firm rather than collaborate with established companies. Consequently, it would be more effective for financial institutions and policy makers to support entrepreneurial activities.

References

- Baldwin, C., Hienert, C., & von Hippel, E. 2006. How User Innovations become Commercial Products: A Theoretical Investigation and Case Study”, *Research Policy*, 35, 1291-1313.
- Camara, G., Fonseca, F. 2007. *Information policies and Open Source Software in developing countries*, *Journal of the American Society for Information Science and Technology*, Vol. 58 No.1, pp.121-32.
- Chesbrough, H.W. 2003. *The Era of Open Innovation*, *MIT Sloan Management Review*.
- Dello Iacovo, L. (2010). *Arduino arriva da Ivrea*, *mittente Massimo Banzi*, December 16, 2010, from <http://www.ilsole24ore.com/art/tecnologie/2010-12-16/arduino-arriva-ivrea-mittente-120937.shtml> (accessed 3 January 2011).
- Ehikhamenor, F. A. 2002. *Socio-economic factors in the application of information and communication technologies in Nigerian print media*, *Journal of the American Society for Information Science and Technology*, Vol. 53, No. 7, 602-611.
- Franke, N. & Shah, S. 2003. *How communities support innovative activities: an exploration of assistance and sharing among end-users*, *Research Policy*, 31 (1): 157–78.
- Franke, N., & Schreier, M. 2002. *Entrepreneurial Opportunities with Toolkits for User Innovation and Design*, *The International Journal on Media Management*, Vol. 4, No. 4, pp. 225-235.
- Franke, N., von Hippel, E. & Schreier, M. 2006. Finding Commercially Attractive User Innovations, *Journal of Product Innovation Management*, 23, 301–315.
- Hienert, C. 2005. *The commercialization of user innovations: the development of the rodeo kayak industry*, *R&D Management* 36/3, 273-294.
- Jeppesen, L.B., & Frederiksen, L. 2004. *Why firm-established user communities work for innovation: the personal attributes of innovative users in the case of computer-controlled music instruments*, June 20, 2004, Copenhagen Business School.
- Jeppesen, L.B., & Frederiksen, L. 2006. *Why do User Contribute to Firm-hosted User Communities? The Case of Computer Controlled Music Instruments*, *Organization Science*. 17: 45-63.
- Katz, R., & Von Hippel, E. 2002. *Shifting Innovation to Users via Toolkits*, *Management Science*, 48(7), 821-833.
- Prandelli, E., Sawhney, M., & Verona, G. 2008. *Collaborating with Customers to Innovate: Conceiving and Marketing Products in the Network Age*, Edward Elgar, London.
- Prandelli, E., Verona, G., & Raccagni, D. 2006. *Diffusion of Web-based product innovation*, *California Management Review*, 48/4: 109-135.
- Sawhney, M., Prandelli, E., Verona, G. 2003. *The Power of Innomediation*, *MIT Sloan Management Review*, 44 (2): 77–82.
- Sawhney, M., Verona, G., Prandelli, E. 2005. *Collaborating to Create: The Internet as a Platform for Customer Engagement in Product Innovation*, *Journal of Interactive Marketing*, 19 (4): 4-17 (first article in the issue and runner-up for best paper).
- Shah, S., K., & Tripsas, M. 2007. *The accidental entrepreneur: the emergent and collective process of user entrepreneurship*, *Harvard Business School, Entrepreneurial Management Working Paper No.04-054*.

- Thompson, C. (2008). Build It. Share It. Profit. Can Open Source Hardware Work?, October 20, 2008, from http://www.wired.com/techbiz/startups/magazine/16-11/ff_openmanufacturing (accessed 2 October 2010).
- Verona, G., Prandelli, E., & Sawhney, M. 2006. *Innovation and Virtual Environments: Towards Virtual Knowledge Brokers*, *Organization Studies*, 27 (6): 765-788.
- Von Hippel, E. 2005. *Democratizing Innovation*, Cambridge, MA: MIT Press.
- Von Hippel, E., Herstatt, C., & Luthje, C. 2003. *User-innovators and "local" information: The case of mountain biking*, *Research Policy*, Vol 34, No. 6 pp. 951-965.
- Von Krogh, G. 2003. *Exploring the open source software phenomenon: issues for organization science*, *Organization Science*, 14 (2): 209–23.
- Yin, R. K., 1994. *Case Study Research, design and methods*, Thousand Oaks: Sage.

Websites

- <http://arduino.cc/blog/?lang=it> (accessed 2 October 2010)
- <http://diydrones.com/> (accessed 7 October 2010)
- http://reprap.org/wiki/Main_Page (accessed 7 October 2010)
- <http://www.adafruit.com/> (accessed 7 October 2010)
- <http://www.arduino.cc/> (accessed 2 October 2010)
- <http://www.botanicalls.com/>(accessed 7 October 2010)
- <http://www.makerbot.com/>(accessed 15 October 2010)
- <http://www.oswash.org/> (accessed 4 January 2011)
- <http://www.sensorex.com/>(accessed 8 January 2011)
- <http://www.sparkfun.com/> (accessed 7 October 2010)