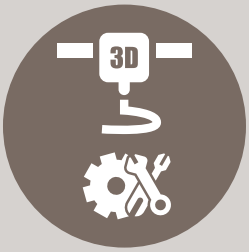


Manufacturing and Consumption

Technology Reviews

- 3D printing for development
- Collaborative economy tools

Kenya, Kisumu
A technician solders a circuit board used for the management of power supply grids.

Credit: James Morgan – Panos

3D printing for development

What is the challenge or opportunity?

The opportunity is the wholesale transformation of material production, supply chains and logistics processes by enabling and making use of local, flexible, efficient, on-the-fly production of the supplies, parts and tools required for critical tasks. The fields that are experimenting with this set of technologies are diverse, and range from industrial design and production, to medical goods and supplies, water and sanitation and architecture.

3D printing as a frontier technology

Additive manufacturing (AM), more commonly referred to as 3D printing (3DP), is not a completely novel technology. Its origins can be traced to the 1980s, when early experimental adaptations of inkjet printing technology led to the substitution of ink with solid materials. Since then, a more or less continual stream of 3DP technologies has been developed, tested and deployed in different settings. This has led to the current 'tipping point' moment, where 3DP is 'coming of age as a manufacturing technique'[36] and is considered to be the cornerstone of a decentralised manufacturing revolution.[37]

Indeed, 3DP has potential to bring about fundamental changes in how a wide variety of products are designed, built, sold and delivered. A number of factors are accelerating the growth of AM processes:

- Rapidly **improving** technologies;
- Falling raw material costs and 3D printer prices;
- Diffusion of AM to new areas, sectors and challenges;
- A growing design-sharing community, both virtual and face to face; and
- Innovations in delivery channels for 3D-printed products.

Over the past three decades, the AM industry has grown annually at a consistent rate of just over 26 per cent, to its current global value of more than $5.1bnn. This is expected to exceed $26.5bn

The current 'tipping point' moment, where 3D printing is 'coming of age as a manufacturing technique' and is considered to be the cornerstone of a decentralised manufacturing revolution.

3D Printers have been used in Haiti for humanitarian purposes since the 2010 Earthquake. Photo credit: Field Ready.

in 2021.[38] While this growth is impressive, experts believe that it could still take a few years before the impacts of 3DP become widespread and create the large-scale transformation that its champions predict.

Definition

AM technologies use 3D printers to directly create 3D objects from digital prototypes and models. Objects that can be printed range in size from nanoscale components to entire buildings. A wide variety of 3DP techniques are currently available, employing materials that range from plastics, metal, ceramic, graphene and glass to paper, food types and even living cells. These materials are provided in the form of powders, filaments, liquids or sheets. The printing process involves forming one layer of the material at a time, each on top of the previous one until the product is complete – hence the term 'additive'. Some 3D printers might melt the material before depositing it in layers, while others use lasers to solidify the material that forms each layer. In the case of inkjet bioprinting, a combination of live cells and supportive scaffolding materials are sprayed or deposited simultaneously.

3DP confers a number of advantages over conventional manufacturing or construction methods based on moulding or subtractive techniques:

- It makes it possible to skip or shorten many conventional manufacturing process steps including design, parts production, transportation, assembly and distribution;
- It also brings considerable flexibility, by enhancing the capacity to apply improvements and adaptations to designs without incurring time or cost penalties;
- It allows the creation of objects that would often be impossible to produce with traditional techniques, including objects with complex internal structures that add strength, reduce weight, increase functionality, or in other ways boost desired performance; and
- It also minimises the waste produced during manufacturing processes.

Current limitations of 3DP, which vary between different printing techniques include:

- Relatively slow build speed;
- Limitations in object size;
- High cost of materials; and
- In some cases, limited object strength.

However, these issues need to be qualified by the fact that each passing year sees new innovations that actively address and reduce these limitations.

There are four distinct usage trends or market segments in the application of AM:[39]

- **Rapid prototyping** – Designers and architects already widely use 3D printers to flexibly create and improve product designs and prototypes.
- **Moulds and tooling** – 3DP is widely used to quickly produce moulds that are used in conventional manufacturing. This in effect combines traditional and AM, and this market segment is currently becoming consolidated
- **Digital manufacturing** – To produce final components and whole products, such as lightweight parts for aircraft or tailored dental implants. It has gained good traction in the past two years and led to unprecedented levels of mass customisation and more efficient, less costly supply chains.
- **Personal fabrication** – The latest trend, and still in a very early stage of development, it refers to entrepreneurs and individual consumers using 3DP to print, share and use or commercialise their own products.

3D printing allows the creation of objects that would often be impossible to produce with traditional techniques, including objects with complex internal structures that add strength, reduce weight, increase functionality, or in other ways boost desired performance.

Potential for acceleration

As 3DP continues to mature and grow, it has the potential to address many important needs. In consumer products markets, 3DP can meet rising expectations for high-quality design and personalisation. Direct product manufacturing using printing reduces the number of steps required for parts production, transportation, assembly, and distribution. It can also reduce the amount of material used – and wasted – in comparison with subtractive methods, thereby potentially reducing costs and negative environmental impacts.[40] In medicine, advances and applications are also accelerating and manifold; from creating models that help surgeons to test, plan and enhance operations and other interventions, through to printing implants, bone replacements, pills and even entire organs.

While the materials used in 3DP remain costly, prices are falling rapidly and can be expected to decline further as demand and volumes increase. In addition, new types of materials are being adapted for AM every year, from titanium for attaching aeroplane engines to wings, to new biomaterials for implants.

Improvements in printer speed and performance, as well as falling costs, are also anticipated to accelerate the spread of 3DP in the coming years. Costs of printers are declining rapidly as production volumes grow and competition increases. On the consumer side, prices for basic 3D printers have declined from $30,000 a few years ago to less than $500 for basic entry-level models. Unit sales of consumer 3D printers are one of the fastest-growing consumer electronic goods categories, albeit from a low base: 23,000 printers were sold in 2011 worldwide, and 278,000 in 2015.[41] Other essential supporting components of 3DP systems, such as design software and 3D scanners, are also continuously enhancing the functionality and affordability of the overall systems on offer.

In medicine, 3D printing advances and applications are accelerating – from creating models that help surgeons to test, plan and enhance operations and other interventions, through to printing implants, bone replacements, pills and even entire organs.

On the consumer side, prices for basic 3D printers have declined from $30,000 a few years ago to less than $500 for basic entry-level models.

3DP marketplaces, first introduced in 2008, are now spreading and becoming more sophisticated. These are web platforms that enable users to share, access and discuss 3D designs and, in some cases, also to commercialise them and print items on demand. Shapeways every month prints and ships more than 220,000 products in more than 50 different materials; and 3D sharing marketplace Thingiverse hosts more than half a million 3D designs at the time of writing. In this way, marketplaces contribute to spreading technical knowledge and the so-called 'maker culture'.[42]

'3D Hubs' illustrates the catalysing potential of such marketplaces. Founded in 2013, 3D Hubs is known as the 'Uber of 3D printers' because it incorporates 'collaborative economy' principles. 3D Hubs allows printer owners to locally advertise and share their printing capacities across the platform's global network, which currently lists more than 31,000 printers in over 150 countries, with hundreds more joining every week (see Figure 5 opposite). Together, they provide over one billion people with access to 3DP within 10 miles of their home, albeit mostly in developed countries.

Potential value generation and impacts

Frontier technologies are characterised not only by their current and potential rate of acceleration but also by their capacity to generate substantial economic and social value in a wide range of domains. The impact on manufacturing and supply chains, and more generally across society, is deemed to be substantial and pervasive.[43] McKinsey Global Institute has estimated a direct economic impact ranging from $230bn to $550bn by 2025.[44]

It is expected that, for a number of years, traditional manufacturing techniques will remain more efficient than AM for high-volume products and parts. However, AM's transformative impact is not so much based on replacing traditional manufacturing but on increasingly complementing and becoming integrated with it and other industrial developments, such as advanced robotics. This normalisation of AM is seen by some as happening faster than anticipated, with 3DP 'becoming mainstreamed as we witness the technology cross the threshold from 'advanced' to 'conventional'.[45]

Figure 5 Global distribution of 3D printers in the 3D Hubs network (2015)

Mirroring digital divides, the distribution of 3D printing hubs is uneven. Source: 3D Hubs, www.3dhubs.com/what-is-3d-printing

On a wider societal and economic level, 3DP's main impact will be as a result of its general capacity to improve productivity, changing patterns of consumption and creating new products, services and entrepreneurial opportunities. Some argue that it could even lead to shifts in comparative advantages between nations, decentralising manufacturing and moving production capacity closer to final consumers, thereby reducing imports of consumer and other goods.

Increased access to 3D printers is contributing to spread a global DIY/maker culture that, inspired by the open-source and hacker movements, leverages collaborative tools and practices to design and construct physical objects. Learning about and socialisation of the maker mentality happens both online, in virtual communities such as HackADay, offline in FabLabs and 'hackerspaces' all over the world and, increasingly, in formal education too. Developments in different related frontier technologies, including cloud computing, internet of things and the collaborative economy are all accelerating this trend. At the broadest cultural level, 3DP could contribute to changes in the way new generations think about how to make things.[46] These new thinking patterns could, in the long term, be the most important impact of 3DP.

Potential benefits for development

It has been argued that 3DP presents a considerable positive prospect for developing countries, because of its potential to be used to promote economic empowerment and improve the livelihoods of communities.[47] Developing countries could use AM to leapfrog industrial development processes, bypassing various elements of traditional manufacturing that are less efficient, more polluting and require a costlier infrastructure. This could reduce dependencies on foreign goods, as a large number of vital products could be manufactured locally on demand. It would also be possible to adapt product designs to make them more suited to local conditions and more culturally appropriate. However, there are also potential economic downsides: AM-enabled industrial development may not create large numbers of new manufacturing jobs because of the high automation levels associated with 3DP manufacturing.[48]

As illustrated in the previous sections, 3DP technology has a broad 'enabling character' that allows it to be used in many different contexts. Housing, emergency response, health, agriculture, sanitation and education are among the many development sectors that have been identified that could benefit from AM.

3D-printed umbilical clamps. Photo credit: Field Ready

Developing countries could use AM to leapfrog industrial development processes, bypassing various elements of traditional manufacturing that are less efficient, more polluting and require a costlier infrastructure.

In the last few years a range of initiatives and experimentation have been conducted to evaluate the suitability of 3DP in developing countries. [49,50] These pilots have shown that AM has the potential to improve response to disasters and development operations.[51] In general, 3DP self-manufacturing can only be considered economically viable in contexts where supply chains fail or are too slow. But these are situations that are quite frequent in humanitarian settings, where supply lead times for urgently needed items can be of up to 12 weeks.[52] Using AM can lead to reductions in lead times to 1–2 days, meaning that unnecessary 'just in case' transport and warehousing could be avoided. Moreover, contextually specific improvements in the design of components has enabled greater functionality and appropriateness. 3DP can therefore lead to improvements that fill gaps and complement existing supply chains, reducing complexity, and time and space requirements, and providing greater flexibility.

The capacity to print on demand is especially useful in the case of medical supplies, where the lack of availability of some low-cost supplies can have unfortunate and unnecessary consequences. Low-cost, modular prosthetics sized according to patients' needs are another promising medical application of AM in developing and conflict-affected countries. 3D-printed prosthetics could in particular better serve children with missing limbs, as they require frequent replacements and refits because they are still growing. For example, Field Ready is a non-governmental organisation that 3D-prints humanitarian supplies in emergency response settings. In 2014, the organisation set up a programme to 3D-print umbilical cord clamps for a hospital in Haiti in response to infant mortality caused by umbilical cord infections. The 3D-printed clamps take just eight minutes to produce and have replaced the often unsanitary makeshift clamps that were being used due to the prohibitive cost of ordering new supplies. The programme provided a printer and training for local staff, and the hospital continues to print enough umbilical cord clamps to keep up with the local birth rate.[53]

Housing is an area that has received special attention after several pilot buildings were constructed using AM technologies. Such initiatives produce housing stock that can that readily be adapted for local climatic conditions and incorporate other features, such as solar panelling, the use of existing natural and recycled materials, and so on. Rapid rates of urbanisation in developing countries and increases in forced displacements due to conflicts and natural disasters have led development organisations to look for new approaches to producing cost-effective emergency shelters and sustainable housing. 3D printers are therefore seen as a potential alternative to current approaches for designing and constructing short-term shelter and housing. However, existing cost structures and technical limitations mean that it is unlikely that AM will become an economically feasible method of producing affordable and sustainable housing in developing country settings for some time.[54]

Enablers and barriers

3DP technology's limitations, particularly the affordability of 3D printers, cost of materials and printing speeds, have so far limited wide-scale adoption. 3D software, scanners and marketplaces are additional and often necessary components for AM systems, and could also limit the successful spread of the technology. However, based on the current evolution of the technology, all these additional components and platforms are expected to improve dramatically in terms of performance and affordability, with key enhancements announced even in the brief period during which this technology review was written.

For example, Hewlett-Packard (HP), the company that dominated 2D printing in the 1980s, in 2014 unveiled its plan to enter the 3DP market. This marked the first entry of a large IT firm into AM. Two years on, its first 3D printers have been launched in what commentators

New models for training are required, including training materials and open source libraries with relevant 3D models, as well as support for new business models that suit developing economies and can benefit urban and non-urban areas.

consider 'potentially the most disruptive event in manufacturing since the invention of 3D printing'.[55] The new technology introduces significant breakthroughs in 3DP speeds, which are up to ten times faster, higher definition, and with lower costs per part. The printers will also soon have multi-material and multi-colour capabilities. HP plans to invest heavily in supporting innovations, including 3D software, new materials and extensive alliances, aiming to achieve 3DP competitiveness with mass production. Other hardware companies, including Toshiba and Canon, are expected to enter the market soon. This upheaval in the 3DP industry signals that technical innovations could accelerate in the coming years, rather than slow down. With them, the manifold impacts of AM on society will also proliferate, opening up new development opportunities.

Such changes will also involve a number of issues and challenges. Risks for 3DP have already been identified that will require state action and regulation to address them. For example, intellectual property rights of products and designs will prove difficult to uphold, as 3D models of copyrighted merchandise can be obtained, modified and shared very easily. The capacity to print food, drugs, biomaterials, and in general, new kinds of products will require special attention too. Guns and other firearms have already been produced using 3D printers, which poses a whole range of security risks. Policymakers face the challenge of evaluating and addressing these risks without stifling innovation or limiting the potential value the technology provides.

In the context of developing countries, additional challenges are especially relevant. AM technologies are normally created assuming usage conditions that are not normally present in international aid and emergency response settings, such as steady power supplies, internet coverage, availability of 3DP expertise, transport and commercial infrastructure, favourable climatic conditions, and so on. The technology and its uses need to be adjusted to account for local conditions if AM is to achieve its potential in development environments.

What next for development sector actors?

The availability of 3DP skills in developing country contexts and among aid workers is an especially important barrier.[56] While 3D hubs are spreading worldwide, in developing countries they are mostly restricted to big cities. New models for training are required, including training materials and open source libraries with relevant 3D models, as well as support for new business models that suit developing economies and can benefit urban and non-urban areas and also improve humanitarian work.[57] For example, FabLabs could be established within local universities and hospitals, and networks of local '3D-preneurs' could be developed and supported to extend a model of sustainable village-based networks of 3D printers.

Most of the advances in the field of 3DP are going to be commercially driven, irrespective of international development efforts. As innovation rates accelerate, and the impact on developing countries becomes more widespread, however, the development community could play an important role as a catalyst to enable the creation of social and economic value for poor and marginalised communities. Systematic projection of the evolution of the technology will be required to identify relevant opportunities and contribute to realising related benefits in development settings using horizon scanning and foresight methodologies.

Risks for 3DP have already been identified that will require state action and regulation to address them... Policymakers face the challenge of evaluating and addressing these risks without stifling innovation or limiting the potential value the technology provides.

Before leaving a site, Field Ready trains local staff to use 3D printers ensuring their ability to print whatever they need (e.g. the aforementioned umbilical clamps). Photo credit: Field Ready.

Donors, particularly, should focus their interventions on those areas and activities where they are best positioned to add value. For example, they might aim to promote innovation by fostering *collaboration between the development community and 3DP networks*, by putting in place strategies that strengthen the 3DP for development (3DP4D) innovation ecosystem as a whole, and thus foster more autonomous emergence, application and scaling-up of innovations. The 3DP field lends itself very well to this treatment. There are tens of thousands of devoted makers who are passionate about the technology and are willing to apply it to every possible situation. Makers are especially keen to experiment and to collaborate, and are motivated by a strong desire to 'build things that matter'. For example, more than 150,000 makers are currently registered with HackADay.io, a community platform that hosts more than 12,000 projects and launches technical design challenges to address 'problems faced by humanity'.[58] Thingiverse has more than 900,000 members and shares more than 560,000 designs.

Because most makers live in developed countries they lack an understanding of the kind of problems 3DP could help to address in developing country contexts. They also lack the connections with people and organisations that could test and improve proposals on the ground. There is huge potential for *mutual learning and cooperation in bridging communities of practice* that include development actors, makers and 3DP private sector actors.

Taking this perspective into account, the following actions would help development actors to catalyse and accelerate progress in the field of 3DP4D:

- **Increase recognition of the potential of 3DP for development** – Development and humanitarian actors need familiarise themselves with 3DP uses, while 3DP communities need to actively learn about the possible ways to contribute to this effort. A targeted research agenda on 3DP4D would keep track of general advances in the field, map outstanding actors and uses in the field, and consolidate evidence and learning about them. Training materials and open source 3DP4D libraries would also be instrumental for the uptake of AM in development contexts.

There is huge potential for mutual learning and cooperation in bridging communities of practice that include development actors, makers and 3DP private sector actors.

- **Convene different actors, at various levels, to promote networking and collaboration** – Devise policy instruments that facilitate network formation and development between the different actors in the field, including development organisations, maker communities, researchers and scientists, entrepreneurs and innovators, local organisations, corporations and business leaders. This would include supporting intermediaries and network-brokers to alleviate the burden of establishing and managing networks.
- **Incentivise new solutions, especially from actors outside the development sector** – Huge potential exists in this field to trigger creativity by means of challenges. Partnerships with existing makers, humanitarian communities and platforms would allow the launch of a series of challenges. Framed appropriately, the challenges would prompt idea generation, and the initial design and piloting of solutions. Challenges would reinforce community-bridging and active co-learning efforts, as well as contributing to establish and mature 3DP4D catalogues. Challenges naturally serve to map and give visibility to the 'positive deviants' in the field and foster replication of their initiatives. These challenges could be for specific 3DP-generated products, but could also be for low-cost, low-maintenance AM systems – the 3DP equivalent of the ubiquitous Nokia 3310 phone.
- **Fund promising new technologies and innovations** – After identifying the most promising actors and technologies, it is important to support their progress from an early stage up to wider diffusion of their solutions. Programmes such as USAID's Development Innovation Ventures, the Humanitarian Innovation Fund and Global Innovation Fund[59] could provide financial support and technical help to consolidate innovation projects at stages when they cannot still attract private funding. These schemes could be applied to AM projects, including mentoring, technical assistance and research to improve and scale up innovations and their associated business models. The Humanitarian Innovation Fund, for example, has provided funding for Field Ready's work mentioned above, which has expanded beyond Haiti to 3D–print a range of humanitarian supplies for emergency responses.
- **Inventive pre-commercial support and procurement of innovations** – Frequently, barriers to adoption do not relate to particular technologies in themselves but to the wider enabling environment. For example, potential users may lack financial capacity to acquire a useful technology, or lack of interest from higher management may deter a development organisation from procuring it. It is thus very important to use the purchasing and influencing power of development organisations to facilitate adoption and consolidation of innovations that have proved to be useful and generate value.

Huge potential exists in the 3D printing field to trigger creativity by means of challenges, to prompt idea generation, initial design and piloting of solutions.

Collaborative economy tools

What is the challenge or opportunity?

Rapid growth in digital social technologies and a growing diversity of approaches to gain income and support livelihoods have enabled new kinds of socio-economic processes. These are built around the sharing and trading of assets and resources, which range from property and vehicles to access to finance and even food. How might these new collaborative business models help deliver development ambitions?

Collaborative economy tools as frontier technology

Collaborative economy tools cover a range of activities designed to maximise the potential economic and social value of existing human and physical resources that may be underused, including intangibles such as skills and tangibles such as physical objects and assets. These tools leverage the power of social networks and technology to promote new models of consumption, novel employment and income generation opportunities. As well as underpinning radical approaches to economic development and growth, they also have the potential to drive greater environmental sustainability.

The promotion of collaborative economy tools in developing countries has the potential to support Sustainable Development Goal 8.3: 'Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services'.[60]

Advocates for the positive social impact of collaborative economy tools include the P2P Foundation,[61] which argues that principles of managing resources for the benefit of the common good, as popularised by Nobel Prize-winning economist Elinor Ostrom,[62] can be implemented through digitally enabled peer-to-peer (P2P) exchange between dispersed individuals and communities.

Collaborative economy tools leverage the power of social networks and technology to promote new models of consumption, novel employment and income generation opportunities.

Examples of collaborative economy approaches

Uber uses a mobile app[63] that allows customers with smartphones[64] to submit a trip request, which the software program then automatically sends to the Uber driver nearest to the customer, alerting the driver to their location. Uber drivers use their own personal cars rather than registered taxi cabs. As of August 2016, the service was available in over 66 countries and 507 cities worldwide.

Airbnb is an online marketplace[65] that enables property owners to list, and property seekers to find and rent, short-term lets and holiday homes.[66] As of August 2016, it had over 1.5m in 34,000 cities and 191 countries.

There has been a rapid expansion in profit-making platforms such as Uber,[67] which is now available in 12 African cities, and Airbnb which as of 2016 has more than 2m listings in 191 countries.[68] The growing use of collaborative economy tools by large corporations indicates a growing trend that such tools are moving away from a primary focus on principles of the commons such as sustainability, openness, and solidarity, to include business principles of competition, profitability and market share.[69] The Collaborative Consumption directory site[70] lists hundreds of businesses that use these business models, ranging from P2P pet boarding[71] to boat sharing.[72]

Definition

Broadly speaking collaborative economy tools refer to a range of initiatives based on enhancing the utilisation of assets by establishing horizontal networks between dispersed users, consumers or participants. Successful tools catalyse and enable new socio-economic systems, typically leveraging digital technologies such as the internet or mobile connectivity, to allow distributed individuals and communities to share, access and use a range of underused assets. Although there is diversity in terms of the ownership of the underlying assets – ranging from those that are collectively owned to those that are individually or corporately owned but collectively accessed – the basic principle underpinning the collaborative economy is the notion of 'distributed power and trust within communities as opposed to centralized institutions'.[73] As shown in Figure 6, collaborative economy tools have been employed in developed country settings in a number of ways, some of which are also growing in developing country settings, such as Airbnb and Uber. New kinds of tools are also emerging in developing countries that take this basic notion and adapt it to local capacities and needs, typically by taking advantage of the rapid growth in mobile phone and mobile money applications.

Successful sharing economy innovations in developing countries often adapt existing models to fit infrastructural realities and limitations. For example, Hello Tractor in Nigeria provides access to essential farm machinery via SMS, allowing small farmers to address issues of undercultivation, poor harvests and lost income.

The key areas identified by the industry body Groupe Speciale Mobile Association (GSMA) as particularly relevant for collaborative economy tools in developing countries are transport and education. For example Go-Jek,[74] the Indonesian 'Uber for motorcycles' launched in 2011, has 200,000 freelance drivers as of July 2016. In an illustration of the 'secondary economy' model posited by GSMA, Go-Jek also offers food delivery, cleaning and beautician services. In Uganda SafeBoda[75] offers not only motorcycle taxis but helmets for passengers and riders, and reflective jackets, thereby improving safety in a country where only 1 per cent of passengers and 30 per cent of drivers wear helmets.

Successful sharing economy innovations in developing countries often adapt existing models to fit infrastructural realities and limitations. For example, in the field of education in Nigeria PrepClass[76] connects independent tutors with students to provide lessons, and provides materials for those preparing for tests. The company has partnered with more than 1,000 cybercafes across the country[77] to allow those without home internet access to access their resources. Hello Tractor[78] in Nigeria provides access to farm machinery via SMS (text message), allowing small farmers to address issues of under-cultivation, poor harvests and lost income.

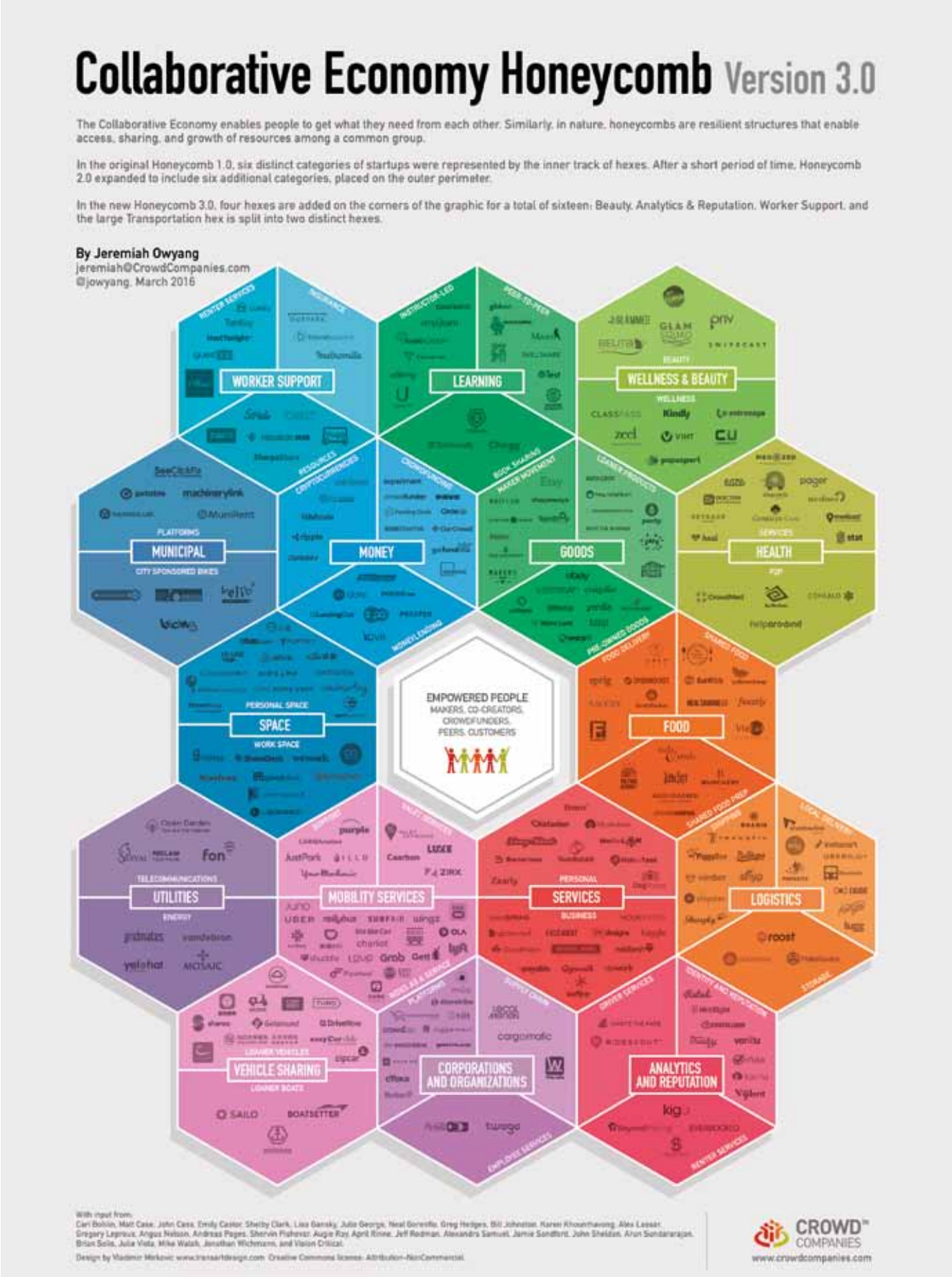
P2P finance projects such as Zidisha[79] exploit the direct communication potential of digital platforms to remove the need for field partners in micro-lending projects and enable individual donors to lend money directly to people in developing countries, using this communication model to facilitate accountability between lenders and borrowers. P2P lending could also work using Bitcoin a digital currency and payment system. Entrepreneurs from developing countries could take out loans in Bitcoin with lower transaction costs, while using the underlying database system as a means of keeping track of and assessing credit-worthiness.[80] Bitcoin and similar technologies also offer the possibility for independent short-term workers – also known as 'gig workers' – to bypass intermediaries by using decentralised cooperative sharing platforms.[81]

According to the UK Royal Society for the Encouragement of Arts, Manufactures and Commerce (RSA), there are two distinct routes to scaling and accelerating collaborative economy tools:[82]

- **Outward processes:** whereby P2P models such as co-working and bike sharing spread through replication across cities and other localities rather than through the network of a single platform.
- **Upward processes:** whereby a single network of activity grows, typically under the control of a single business, which then has the potential to expand nationally and globally through the use of technology.

Outward processes have been facilitated by technological breakthroughs such as electronically locking cars, bike racks and locks, telecommunications systems, smartcards and fobs, mobile phone access, and computers on board vehicles. More generally, P2P models have grown considerably to number hundreds if not thousands of programmes worldwide.[83]

Figure 6 Collaborative economy honeycomb



The collaborative economy continues to expand into more and more sectors. Source: crowdcompanies.com. Design by Vladimir Mirovic www.transartdesign.com, March 2016. Creative Commons licence: BY NC.

The *upward* approach is clearly visible in the five main sectors that have been enabled by collaborative economy tools: P2P finance, online staff resourcing, P2P accommodation, car sharing and music video streaming. Professional services firm PwC estimates that the global revenues of these five collaborative economy sectors combined has the potential to grow to from around $15bn today to $335bn by 2025.[84] It is anticipated that this will happen as the result of broader changes in consumption and asset usage patterns and behaviours. For example, a World Economic Forum survey looking at 'technology tipping points' found that two-thirds of respondents expected people to make more journeys using car sharing than in private cars by 2025.[85]

A 2013 report shows that collaborative economy tools are starting to reach groups that were previously excluded from the global economy, and may have started to promote a type of economic development that is more connected with traditional social values and environmental concerns of local communities.

The rapid rise of smartphone ownership rates in emerging and developing nations – climbing from a median of 21 per cent in 2013 to 37 per cent in 2015[86] – might well facilitate the spread of collaborative economy tools, both outwards and upwards. A 2013 report by International Development Research Centre (IDRC) on the impact of collaborative economy approaches in developing countries shows that they are starting to reach groups that were previously excluded from the global economy and may have started to promote a type of economic development that is more connected with traditional social values and environmental concerns of local communities. In particular, IDRC's research on women at the bottom of the pyramid shows that the sharing economy might have a positive impact on issues that are key inputs for economic growth – such as trained labour, capital and technological development – through initiatives that offer training and P2P loans. However these economic models did not have the potential to affect housing, which is a significant concern for women at the bottom of the pyramid.[87]

Potential value generation and impacts

GSMA, whose Ecosystem Accelerator programme is funding mobile-focused sharing economy projects in emerging markets,[88] identifies the following economic benefits:

- Increased access to tools and other useful physical resources;
- Increased ability for individuals to live off cash flow, with less need for savings to be able to afford use of assets;
- Better asset utilisation;
- Less opportunity for long-term abuse of trust because of direct and public feedback loops; and
- Creation of secondary economies through services such as Uber drivers delivering goods or food.

Overall, there would seem to be considerable potential for collaborative economy tools to contribute to diversification of income generation, asset utilisation and livelihoods options in developing countries.

However, this value is also closely related to levels of connectivity and affordability, so it is also likely to disproportionately benefit urban, literate, educated and well-off people. IDRC points out that as crowdfunding platforms require the engagement of middle- or high-income groups, although shared resources can be important to low-income groups, existing solutions – such as bike-sharing services – can be out of their reach.[89]

It is also important to recognise the impact on established businesses that are 'disrupted' by collaborative economies. For example, in New York City alone, Airbnb's 416,000 guests[90] who stayed in houses and apartments between 2012 and 2013 cost[91] the New York hotel industry 1m lost room nights.[92] On a broader societal level, the casualisation of employment that these business models cause has an impact through the erosion of workers' rights and lack of healthcare and insurance benefits.[93]

Potential benefits for development

As noted above, the sharing economy has the potential to reach groups that were previously excluded from the global economy thanks to growing access to open global platforms, the internet and mobile phones in poor communities around the world.

In particular, granting access to millions of citizens previously locked out of capital-based marketplaces could diminish certain forms of asset-based inequalities and boost inclusion. For example, innovative projects that do not 'fit' existing funding models can access capital through P2P lending platforms such as Zidisha, which allow lenders to connect directly with borrowers in developing countries.

Projects such as Jana[95] take advantage of widespread mobile phone adoption in developing countries to pay people with airtime for contributing to research or participating in social marketing.

Samasource, a collaborative economy human resources firm, provides an entry point to employment for groups historically excluded from formal employment, such as women, young people and refugees. Samasource offers microwork opportunities to people from the bottom of the pyramid without significant work experience, and trains them to perform basic digital tasks such as image classification, data verification and content moderation, offering a living wage for completed work. The company claims that they it can raise users' average salary from $2.20 a day before joining, to an average of $8.15 after three and a half years.[96]

To ensure value for people at the bottom of the pyramid, GSMA research suggests that it is better not to let platforms co-opt people. Instead it is vital that individuals can opt in and out, with the platform simply acting as an intermediary, and that assets are owned by people, not by platforms.

Enablers and barriers

Key enablers and barriers of the sharing economy in developing countries relate to ownership of assets and the regulatory environment, as well as modifying technology models to fit local needs and access.

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The same research also suggests that it is important that collaborative economy startups work with and not against the prevailing regulatory environment. GSMA also warns that it is vital for platforms and individuals not merely to replicate existing services, but instead seek to leverage the power of digital technologies to offer new solutions that prove a better fit in developing countries. For example, in Western Europe and the United States sharing economy platforms rely on users having smartphones, good mobile data access and a credit card. However, in developing countries these platforms must be tweaked to use technologies such as SMS, interactive voice systems, and mobile money platforms such as MPesa. Each of these technology adaptations offers potential entry points for mobile network operators, businesses, consumers and development organisations.

On a similar theme, IDRC also suggests that entrenched solutions and monopolistic companies, which these new business models of sharing, openness and transparency could displace, may put up resistance.[97] Non-existent supply chains and distribution channels, bad roads, and lack of financial access might also present barriers to the spread of collaborative economy tools, as well as low literacy rates and lack of shared languages. However, it is worth noting that in contexts where collaborative economy transactions are feasible, they could potentially lead to a decrease in financial corruption, because they are often mobile based and transparent.

Risks and downsides

The rapid growth of sharing economy platforms poses a clear risk of the rise of 'networked monopolies'. The RSA has found that some global collaborative economy-based platforms are showing signs of 'monopoly power in influencing the price, output, and investment of an industry, as well as in limiting the entry of new competitors'.[98] There is also a risk that businesses such as Uber do not contribute to an economy's overall productivity. While the company raised $350m from Saudi Arabia's sovereign wealth fund in 2016,[99] critics argued that the company's growth does not generate 'positive spillovers'[100] on a scale that might benefit other businesses.

There are also issues in relation to labour rights and conditions. A *Harvard Business Review* article from 2016 found that far from being a neutral intermediary, Uber's operations are based on a highly managed labour force:

> Drivers have the freedom to log in or log out of work at will, but once they're online, their activities on the platform are heavily monitored. The platform redistributes management functions to semi-automated and algorithmic systems, as well as to consumers.[101]

In a development context where the achievement of women's rights is a priority, it is possible that such employment models might favour men, who typically own assets such as cars, which they can leverage. Women with childcare responsibilities might not be in a strong position to take advantage of some of the flexible working models offered. Although women who do care work may be well positioned to perform gigs that could be done from home, they may find it more difficult to engage in other 'flexible' gigs outside of the home such as driving for Uber.

Such systems might also pose a threat to individuals through the erosion of workers' rights and full-time employment, and the disappearance of health-care and insurance benefits. In his research on digital work platforms Mark Graham from the Oxford Internet Institute warns of the dangers of digital work platforms for freelancers 'in which competition between workers leads to a race to the bottom in terms of wages and working conditions'.[102] World Bank research shows that unions significantly increase wages and working conditions;[103] the lack of effective workers' representation on collaborative economy-enabled platforms could pose a threat to individual wellbeing and wages.

A Go-Jek driver in Jakarta, Indonesia, checks for his next job on his phone. Go-Jek, the motorcycle equivalent of Uber, has 200,000 freelance drivers signed up and as well as providing rides, offers food delivery, cleaning and beautician services. Photo credit: Bernard Oh on Flickr, creative commons 2.0 BY NC ND.

The World Economic Forum also warns that increased employment flexibility can leave workers vulnerable and lead to what it describes as an 'agile but fragile workforce',[104] whose working lives are characterised by short-term and zero-hour contracts. This in turn has macro societal and economic impacts, with the need to overhaul traditional organisational structures.[105] Economic and political changes are required to adapt to collaborative economy models.
For example, the collaborative consumption economy is hard to tax, measure or regulate, so it will be necessary to rethink how to deploy effective tax systems, pension schemes and trade unions. Taxation and regulation will need to move ownership- or sales-based modelsto use-based models.

Gig economy systems might also pose a threat to individuals through the erosion of workers' rights and full-time employment, and the disappearance of health-care and insurance benefits.

What next for development sector actors?

The sharing economy offers not just a means to promote the economic welfare of some of the world's poorest people, but could become a new model for development, building on values of self-help and solidarity which already exist in certain communities. This puts the onus on development sector actors to promote the social benefits of collaborative economy tools and to explore ways to ensure that hard-to-reach groups benefit from these models.

One route to this might be through funding innovation challenges and experiments to pilot new projects, taking advantage of the fact that digital sharing technologies designed for the bottom of the pyramid can be very cost effective in terms of impact. This might also have the effect of bringing together different actors to create new collaborations and incentivise new solutions.

A number of pro-poor collaborative economy businesses might benefit from investment to help them grow and reach new markets. The work done by GSMA[106] shows how the private sector can help secure the funding and direction innovators in the sharing economy need to bring their products and services to scale. This has related benefits, providing new business opportunities for mobile network operators.

Finally, development actors can play a role in brokering groups of experts to address issues such as the need for new regulatory frameworks, which are required to address critical issues such as tax system reform and quality standards.

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