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innovations

TECHNOLOGY | GOVERNANCE | GLOBALIZATION

Making in America

ENTREPRENEURIAL SOLUTIONS TO GLOBAL CHALLENGES

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Lead Essays

Case Narratives

Analysis

Organization of the Journal

Each issue of *Innovations* consists of four sections:

1. Lead essay. An authoritative figure addresses an issue relating to innovation, emphasizing interactions between technology and governance in a global context.

2. Case narratives. Case narratives of innovations are authored either by, or in collaboration with, the innovators themselves. Each includes discussion of motivations, challenges, strategies, outcomes, and unintended consequences.

3. Analysis. Accessible, policy-relevant research articles emphasize links between practice and policy—alternately, micro and macro scales of analysis. The development of meaningful indicators of the impact of innovations is an area of editorial emphasis.

4. Perspectives on policy. Analyses of innovations by large-scale public actors—national governments and transnational organizations—address both success and failure of policy, informed by both empirical evidence and the experience of policy innovators. The development of improved modes of governance to facilitate and support innovations is an area of editorial focus.

Cameron Colby Thomson and Marcin Jakubowski

Toward an Open Source Civilization

Innovations Case Narrative:
Open Source Ecology

At Open Source Ecology (OSE), we design and manufacture, and help others design and manufacture, devices like tractors, bread ovens, and circuit makers. Much as Wikipedia has sought to democratize access to knowledge and the open source software movement has attempted to democratize computing, Open Source Ecology seeks to democratize human wellbeing and the industrial tools that help to create it. As Digital Democracy founder Mark Belinsky put it, we make "victory gardening tools for your victory garden." We design our tools in a nontraditional way with nontraditional goals in mind, and we design them to work with each other.

We call our interconnected set of devices the Global Village Construction Set (GVCS), which, upon completion, will include 50 simple modular open source tools that are designed to provide modern comforts and basic material autonomy.[1] The GVCS tools are designed simply so they can be used to replicate themselves and are easy to modify and customize. Much like the Erector Sets we used in our childhoods, the tools have interchangeable Lego-like modular components and quick-connect couplers. The open, collaborative nature of the GVCS project means that the toolset can, in principle, be independently adapted for the American farmer, the African technologist, or the pioneering lunar colonist.

If the plans for the iPhone were open sourced, the average consumer, innovator, or manufacturer would still be helpless to replicate one, let alone participate in its design, because to make an iPhone, everything has to fall in to place. Governments need to function effectively, ships must sail and trains need to leave the station on time, workers need to show up on the job, the weather needs to cooperate, and all the materials in the supply chain must be on hand. At that point, the highly proprietary equipment and manufacturing processes are put in motion. The robust image of our modern economy in fact depends on a small miracle taking place each day within our labyrinthine supply chain. In contrast to the iPhone's

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Marcin Jakubowski, PhD, is the founder of Open Source Ecology.

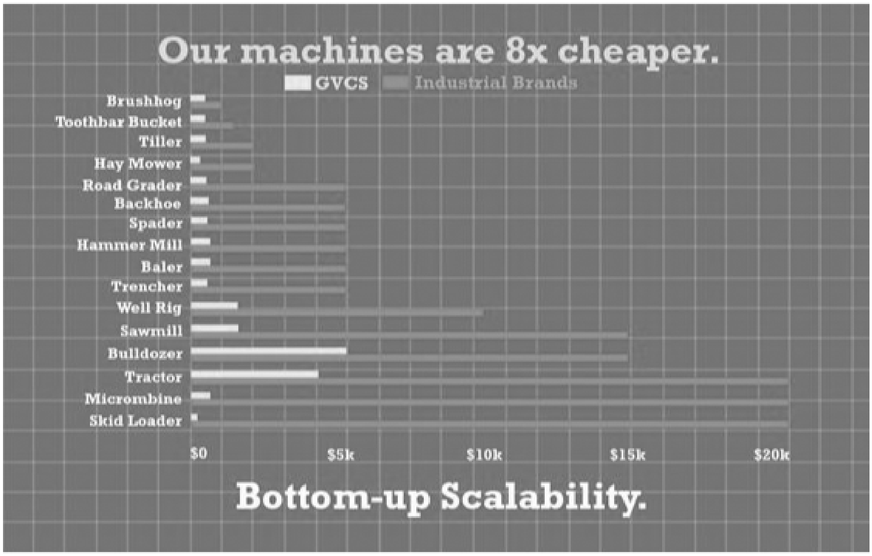


Figure 1. Simplicity brings many benefits, including cost savings

design—which uses African minerals that are assembled in China with parts from Japan—contributors all over the world have designed the GVCS so that its supply chain is no farther than the backyard and the local scrap heap. Its subcomponents range from basic manual manufacturing to highly automated, software-based precision tools. The GVCS represents the natural intersection of the open software and open hardware movements with basic human needs. Some of the tools are thus far only rough sketches, but a surprising number are real and in active development.

THE ORIGINS OF OPEN SOURCE ECOLOGY

Open Source Ecology essentially began when Marcin Jakubowski's tractor broke down in rural Missouri. A Polish immigrant who had experienced a crisis of meaning after completing a PhD program in fusion physics, Marcin had made the unlikely choice of farming as a profession. As a natural tinkerer, Marcin was frustrated by the fact that his tractor was unnecessarily difficult to fix and that he could not afford the expensive replacement parts. So, he designed a new tractor himself and put the design on a wiki. His decision to design a flexible, easy-to-fix tractor and then to open source it inspired a community of do-it-yourself (DIY) contributors to his wiki and the birth of a new collaborative movement.

Marcin explains his personal evolution this way:

> Growing up in Poland and having a grandparent [who was] in the concentration camps, I was aware even at an early age what happens when

The Global Village Construction Set.

> materials are scarce and when people fight over opportunity. It's what drove me to identify the 50 machines, from cement mixers to 3D printers to moving vehicles, that will allow a working society to be created. My goal, and my daily life, is dedicated to open source these tools, so that anyone—from the remote villages in Third World countries to small enterprise in the developed world—can have access to these meaningful tools to create a better life for themselves. EVERYONE needs access to these tools—it's why we're creating them with an open source model, and with the most advanced digital and physical technology known to us today. The intended outcome for these tools is for 12 people working for a mere two hours per day, purely from local resources, . . . to sustain themselves and take advantage of a modern economy. The goal is to build cities from the ground up, and in harmony with the very nature of the planet we inhabit. With these tools, and with this outcome, I hope to decrease the barriers to human potential—freeing up human capital to achieve the higher goals of awareness, actualization, and invention.

After researching and engaging with special-purpose communities and existing open source projects and collaborators, Marcin began to piece together a larger plan. He repurposed his farm as a prototype location for open source manufacturing and self-testing. He began to construct the buildings and develop new-generation devices using his own tools and technologies. He created prototypes for several machines, and as these prototypes were refined, Marcin put their test results and documentation on his wiki. The Internet community responded not just by

Tinker Toys at Scale, an early prototype

contributing additional designs but by sending money. Marcin thus created one of the early crowd-funding campaigns, designing a system that enabled donors to sign up to make monthly $10 donations via Paypal. These "true fans" soon numbered more than 500, and Marcin calculated that with this funding he could develop the initial machines. Having cleared $25,000 in sales from the initial prototypes, it became clear that additional development could be bootstrapped by these early collaborators.

During this time, Marcin attracted the attention of the TED Conferences. He was invited to speak and to become a TED Fellow. The experience was explosive. His TED talk was widely viewed, the community began a Kickstarter campaign, and donations from the Ewing Marion Kauffman Foundation and other leading foundations began to flow in. South African open source legend Mark Shuttleworth, creator of the Ubuntu Linux operating system, offered his organization's assistance and a donation large enough to significantly expand the project's prototyping efforts.

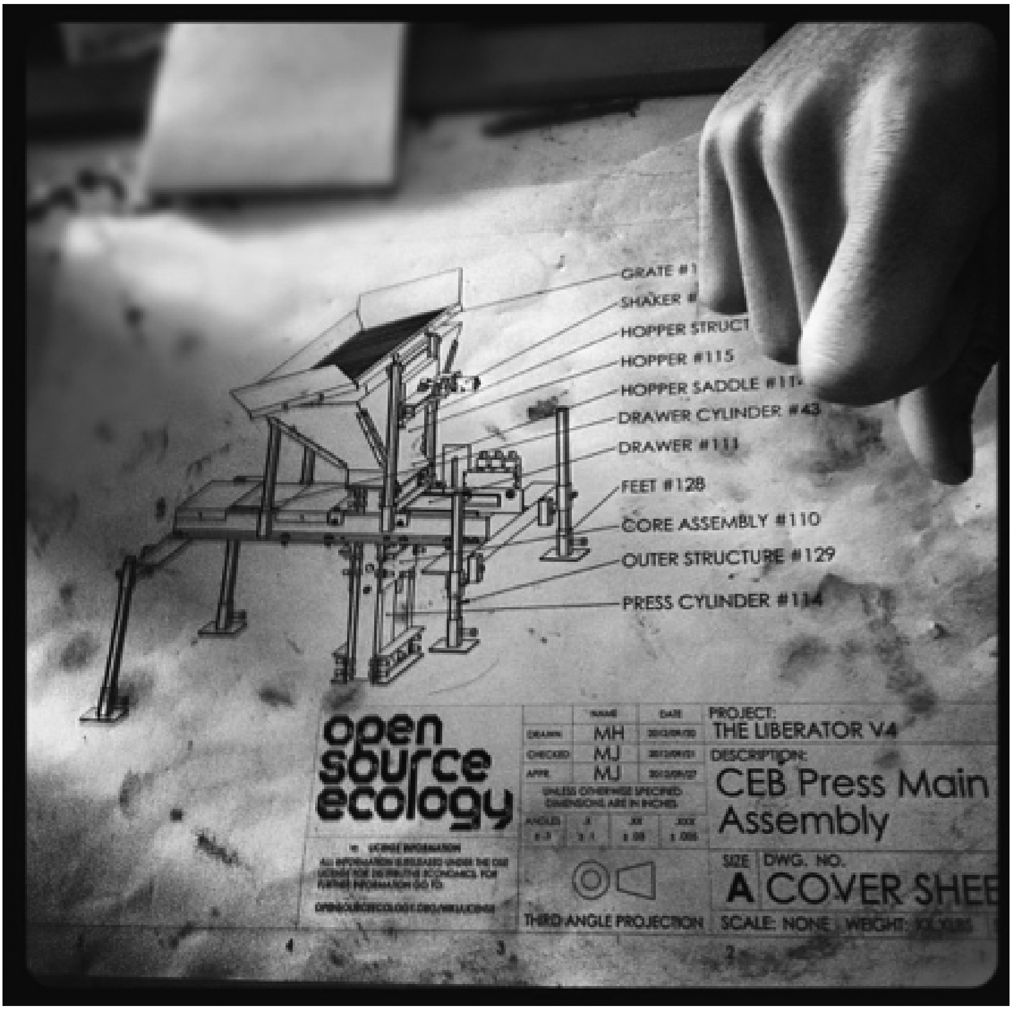
A core value of Marcin's newly constituted team was to maintain completely open communications and planning by providing wiki and video documentation of each step. The investment in video and detailed online documentation for the project and the attention of early ecological journalists and documentary filmmakers provided unprecedented public access to the team's progress. Outreach via

The LifeTrac multipurpose tractor attached to an old hay rake

social media also began to attract key contributors, documenters, volunteers, and collaborators in larger numbers.

During this phase, a more intensive community-building effort began at the Open Source Ecology headquarters in northern Missouri, which was known as the Factor e Farm. The OSE team prepared to scale manufacturing and design, and began using the GVCS tools to build a green manufacturing facility and habitation buildings on site. The buildings were constructed using locally pressed bricks from our compressed earth brick press prototype, which demonstrated that the core cost of the buildings could be eliminated and the barriers to affordable housing be reduced.

It was during this time that I met one of the key contributors to OSE, an incredibly bright 19-year-old Korean Canadian named Yoonseo Kang, who had come to the farm to work on the GVCS rather than attend Princeton. I met Yoonseo in the middle of a field late at night, carrying his laptop and wearing a hard hat as he updated the Arduino software we were using on the brick press.[2] He was working in the pitch black so the facilities could be completed before the first frost. Like Marcin, Yoonseo's origins gave him insight into the stark contrast between life with and without the benefits of industry. Despite immigration issues and the initial disapproval of his parents, Yoonseo went on to win the Thiel "20 Under 20" Fellowship for his work at OSE, which paid him $100,000 to continue his efforts and postpone attending college. He is now building an open source



Detailed designs and instructional videos accompany each product

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CNC Torch Table, a computer-controlled machine that quickly cuts intricate patterns out of large steel sheets.

Many collaborators and interested parties like Yoonseo Kang have come out of the woodwork over time, and OSE now faces the challenges of rapid growth and the simultaneous development of additional machines. While the team still searches for high-level contributors who have the skills needed at the farm, spontaneous replication of the GVCS devices has started occurring in the world at large, far from northern Missouri. They were showing up via photographs and videos the makers emailed to us. A few days before the writing of this narrative, two high school students in Pasadena, California, made an OSE LifeTrac tractor with modified wheels in their shop class. A man in Italy replicated the OSE Liberator Compressed Earth Brick Press and wrote a blog entry about it. These moments bring cheers from our group when shared over dinner.

Top: *Gabi, our farming manager, cutting the hopper for the compressed earth brick press*

Bottom: *The hopper on the finished Liberator Compressed Earth Brick Press*

Dinner discussions are where one can see the working of the organization with clarity: the procurement process needs debating, crops need planting, one of the walls remains without stucco, and a single cow wanders around munching on the front lawn as we eat. One of the prototype LifeTrac tractors has sheared its wheel connector while attempting to use a newly designed trencher attachment to bury a water line. OSE is a work in progress, but progress is being made, and surprisingly quickly.

Still, creating the GVCS is an extremely grand goal. Formally defined as "a minimum set of technologies necessary to create advanced civilization from locally available 'dirt and twigs' with 12 people and 1 year of time[,] starting with a container-load of GVCS tools," the GVCS project could hardly be more ambitious. Each device comes with complete documentation, as well as manufacturing and assembly videos. The combined product of device and documentation is called the Civilization Starter Kit. The first edition has just been released, and new devices and iterations for the second release already are under way. The momentum and the ambition are palpable on the farm.

ENABLING INNOVATIONS

Open Source Ecology's rise to significance was made possible by the environmental conditions seen in the rising tide of the open source, open knowledge, DIY manufacturing movements. In order to achieve its current level of success, a number of innovations were put in motion by both the open source community and the OSE core team.

The first was the application of existing software development paradigms to the physical world. This is seen as an emerging trend, and is documented by OSE collaborator Joe Justice's Team Wikispeed open source car project, which he has been contributing to our effort. Joe's project leaned heavily on these paradigms as they progressed in their attempt to create a 100-mpg car to enter in the Progressive Automotive X Prize competition. By emphasizing rapid prototyping, modularity, and re-use from computer science paradigms, along with agile development and scrum management processes, the budgets, team size, and timelines for the projects were lowered dramatically. Rather than borrow more directly from manufacturing paradigms such as Kaizen, Kanban, and Six Sigma, the movements oriented more closely with their software counterparts, OSE developed a number of novel innovations in this area in order to meet its mission. One is a documentation procedure we call the Fabrication Diagram.

The Fabrication Diagram facilitates the building of a prototype machine. The diagram contains a visual representation of all fabrication steps and parts, which builds on the kind of ideas that allow shoppers to assemble their flat-pack furniture purchased at Ikea, but with much greater capability. The visual representation allows the fabrication team to understand which steps may be taken in parallel and which must be done sequentially, and in what order. Each step links to a fabrication drawing. The supporting files are arranged in folders that are tagged to the step. By visually placing fabrication steps horizontally on a page, we indicate to the builder that several steps can be taken in parallel. Items going vertically down the page are subsequent steps that are dependent on prior parts being fabricated. This technique is useful when a team of fabricators is involved in rapid and parallel production. Using this method, we aim to build a large compressed earth brick press in one day with eight people. Initial prototypes of the press, which can be constructed from relatively inexpensive parts, have been sold for a healthy profit ($5,000+); an industry-standard machine with a comparable brick output is approximately five times more expensive. Inexpensive parts and simple, efficient fabrication dramatically increase the accessibility of the device. Each of our products is designed with similarly simple construction from standard parts, and minimal experience is needed to construct them.

A second innovation was the ability to stand on the shoulders of existing innovations and other open source communities. Already mentioned are the contributions of crowd-funding services and development tools, but the team relied most heavily on simple tools such as Wikipedia's MediaWiki to document the ballooning database of designs; Inkscape vector art and Google SketchUp to allow the contribution of designs; and inexpensive Arduino open hardware kits to make control devices possible. These tools democratize the contribution process in crucial ways. Even tools as mundane as LibreOffice and Google Docs text editors are indispensable for contributors in regions where commercial licenses may cost as much as a year's income. Finding good, freely available CAD software is still a problem. However, despite its deficiencies, Google SketchUp can be effective simply because more users have access to it. A swarm of people of using SketchUp can produce designs and fabrication drawings faster than a single draftsperson on a proprietary CAD platform.

While our design principles dictate that we adapt traditional designs to be modular and easy to manufacture, we rely heavily on the entire body of historical manufacturing innovation. We start with the industry standard design and strip away all unnecessary features. As a distributed open source collaboration, one of the most common types of forum posts we receive is like this: "I worked for many years as a systems engineer for Boeing and am now retired. I have started putting some pages together on the subject in the wiki. It's very preliminary, but I intend to keep working on it." Like other open source movements, people want to work on things because they have them in their blood. Some of the machine designers benefit from a lifetime in the business, and others are in completely new territory. Either way, the combined knowledge of the community goes into every innovation through our distributive and iterative prototyping and replication process. We have even run design competitions using GrabCad to crowd source design. Any out-of-touch design elements encountered in use locally are improved or wholly refactored by replicator and contributor feedback and contributions.

The OSE license, called the *OSE License for Distributive Economics*, is an important and challenging aspect of design that makes this adaptability possible. The OSE license uses the Creative Commons CC-BY-SA 3.0 license, which is sim-

INTELLECTUAL PROPERTY REGIME	ACCESS TO TECHNOLOGY BLUEPRINTS	ACCESS TO OUTSIDE PARTICIPATION IN DEVELOPMENT	ACCESS TO ENTERPRISE BLUEPRINTS
Proprietary	**No**	**No**	**No**
Open Source	**Yes**	**Yes**	**No**
Open Business Model	**No**	**Yes**	**No**
Distributive Enterprise	**Yes**	**Yes**	**Yes**

Figure 2. Levels of openness in human enterprise, guaranteed by each format

ilar to the GPL license on which Linux is based. Our original license was based on an attribution-based license in the public domain that was similar to BSD, the open source operating system on which Apple's OSX is based. The viral ShareAlike aspect of the new license allows contributors to use our designs for free for any purpose, provided that they contribute modifications under the same terms in return; the public domain does not impose this restriction. While our team was against coercion of any kind, we wanted to maximize total innovation, thus we decided that the ShareAlike attribution best reflected our values and encouraged our public goals. In addition to this license, we suggest to prospective licensees the explicit ethical intent of creating a *distributive enterprise*, which is a term OSE coined to describe an enterprise that not only has an open source product and a user-contributed design but also open sources its entire business plan and procurement strategy. This element is incorporated into what is referred to in the CC-BY-SA 3.0 as our "moral authority" in the license.

We are taking this stand to make it explicit that our content is intended to contribute to the open source economy. Our aim is to raise awareness of distributive enterprise as a foundation for an economic system, to reduce artificial material scarcity, and to define our design specifications in the interest of environmental regeneration and social justice. Various international jurisdictions handle the concept of inventor moral authority differently, and the CC-BY-SA 3.0 is an innovation that helps make this more easily possible.

THE DISTRIBUTIVE ENTERPRISE

A distributive enterprise is a social enterprise that focuses on open economic development. More specifically, it is a transparent enterprise that promotes—at the core of its operational strategy—the capacity for others to replicate the enterprise without restrictions. You might think of it as an open franchise system that focuses on being replicated by others. This involves the availability of documentation and training materials, wide access to required technologies, and other elements that enable collaborative production and repeatable results. Without these characteristics, a modification does not fully achieve its goal of being part of a system of economic relocalization and flexible digital fabrication that uses community

Trends in Open Contribution

Access is key: Open source hardware specs and interfaces allow adaptation by and participation in the distributed production community. Expert communities optimize the velocity of innovation by shortening iteration times, lowering the barriers to entry, and democratizing contribution and documentation.

Hardware is now software: 3D printers, automated cutters, and other tools allow hardware to be copied and shared as if it were software. The ability to fork hardware designs and the benefit of common API and interchangeable parts are understood through the analogy to the service-oriented architecture and other design patterns in software engineering.

Hardware is customized: Devices are optimized for environments in which resiliency, adaptation, end-user serviceability, modification, and other goals are paramount. Modification and modularity allow general-purpose efficiency to exceed special-case efficiency—at lower cost. Mass customization and "long tail" innovation open new markets and allow the satisfaction of market niches previously too small to be addressed.

knowledge. We call the minimum unit of complete production the OSE Microfactory; one of our major goals is to have OSE Microfactories internationally distributed within the next five years.

Our moral aim is to work globally to stop material constraints from determining the wellbeing of humans, thereby eliminating production as an issue of control and power. The goal is to address the issue of artificial scarcity and disparity of wealth as related to peoples' lifestyles, global geopolitics, and corrupt leadership. Another goal is for the economic system and lifestyle choices to embody a higher purpose.

To test the usefulness and success of its results, a distributive enterprise "dogfoods" its own products, as we have done at the Factor e Farm by using our own tools to build our subsequent tools and facilities. Participants in distributive enterprise aim to blend their lifestyle with their work as an expression of consistency between one's values and one's actions. This creates a greater interest in addressing pressing world issues by making citizens directly connected to the literacy of production and consumption. The distributive enterprise concept builds on the notions of appropriate scale proposed by E. F. Schumacher and of economic Swadeshi proposed by Mohandas K. Gandhi, which have been updated by bringing them into the digital age, where information can be shared readily and globally.[3] The distributive enterprise model is an expression of human-centered economics of collaborative production, whereby citizens regain their autonomy in a complex world.

This goal helps to create a parallel open source economy that is similar to the open source software movement, and which captures a portion of the production of food, energy, housing, fuel, transportation, electromechanical technology, and microelectronics. By definition, an open source economy is one that is maximally efficient and where efficiency refers to the capacity for putting innovation in the greatest number of hands, which enables producers with any level of capital resources to participate, and provides them with a structured franchise-like blueprint to do so.

From TechShop and Langton Labs in San Francisco to iHub in Nairobi, there is now an emergence of community hacker and maker spaces in urban areas around the world that utilize open source tools. There also is strong growth of a different sort of community in rural Midwestern and coastal areas where the economies are greatly oriented toward agriculture and industry. One such community is Turbine Flats. Located in a large warehouse in Lincoln, Nebraska, Turbine Flats houses its software development, marketing, and R&D in a space it shares with woodworking and metal-working operations. The Mastercraft in Omaha, Nebraska, is an even larger prototyping location and artist community. Community CROPS in nearby Lincoln transforms unused community space into a training ground for citizen farmers. Similar organizations have developed across the nation, each with its own unique flavor, many of them operating purely for the education and entertainment of their patrons. Some, like OSE, have located in regions where they can be free from building codes that would prevent essential experimentation, while others have cropped up adjacent to industry. In a burst of creativity triggered by a nearby military industrial robotics center, Artisan's Asylum in Massachusetts has grown a giant hydraulic hexapodal walking robot using hydraulic technology similar to that used in OSE's LifeTrac tractor. With the democratization of precision machines, automated manufacturing, and open source plans and business models, all active participants have a larger and larger body of resources to build on, whether motivated by fun and education, profit, or social benefit—and regardless of location. These community spaces increasingly use the kind of open source hardware that OSE and others are developing, and they increasingly provide apprenticeships as an alternative or supplement to formal education.

TECHNOLOGY AND THE ECONOMY

When I discuss Open Source Ecology with policy analysts, a variety of topics come up, such as the reduction in sales/use tax receipts that results from an economy increasingly oriented toward self-production and bartering. Reduced sales taxes may well be counteracted by a localization of the economy, increased local tax receipts, and a decreased dependence on imports for basic staples, but in any case, I do not expect tax receipts to be of significant concern. California recently succeeded in getting Amazon to withhold sales tax after 20 years of interstate tax freedom, and given the incredible variety of tax strategies across state and national jurisdictions, I have no doubt that governments will eventually notice and respond to changes in their receipts. More important, however, is the larger upside for the economy and the individual. If we look at the federal budget, we see that less than

25 percent is spent on nonmilitary elements we would consider governance. The primary and most rapidly growing component is entitlement spending directed toward the health and material wellbeing of our aging population. The same is true globally. If technology improvements can fuel increased innovation, a more equitable distribution of wealth, and improved material well-being - then these economic benefits outweigh any negative consequences of reduced taxation.

Much as the garage hackers fueled the computing boom, the garage manufacturing revolution is making the manufacture of tools that was once the domain of a few corporations accessible to everyday people. This is exactly the kind of creative destruction that economist Joseph Schumpeter would have been proud of. As investor Marc Andreessen has commented, all industries are being "eaten by software"; that now includes hardware, the industrial system, and the physical world. Andreessen also remarked that, "over the next 10 years, the battles between incumbents and software-powered insurgents will be epic." And they had best be, as stabilizing or declining populations and natural resources in developed parts of the world imply that GDP growth can only continue through gains in efficiency and innovation. GDP is a function of human labor, efficiency, and natural resources, and with the other two factors down or flat for the near term in the developed world, our growth-based economy is wholly dependent upon improvements in efficiency and innovation.

Once a manufacturing powerhouse, Japan is facing record levels of debt and has recently reported the unthinkable: a potential decline in real GDP combined with the stigma of a continually falling population. The U.S. is saved from a similar fate only by immigration and first-generation immigrant birthrates. As Adam Smith pointed out in *The Wealth of Nations*, governments compete and maximum welfare exists by maximizing innovation and the distribution of innovation. In his recent ruling on the case involving Google/Motorola and Apple, Judge Richard Posner explained why he wouldn't ban Motorola products from the shelves: "An injunction that imposes greater costs on the defendant than it confers benefits on the plaintiff reduces net social welfare." Posner later stated that "most industries could get along fine without patent protection" and in so doing revealed the elephant in the room that every technologist is aware of: the patent system in most rapidly evolving industries is hindering innovation and, counter to its raison d'être, is actually reducing net social welfare. The argument for nationalistic protectionism by closed sourcing appears to be similarly discredited in the consumer sector, given that China has already demonstrated its ability to copy and manufacture nearly all products and services. Bringing China into an innovation ecosystem allows other countries to benefit from its contributions, as China has the highest level of manufacturing expertise for an increasing number of key consumer items. It is staggering to estimate the number of people in the developed world who are involved in the innovation process, and then consider engaging millions if not billions of African and Asian inventors. Given that innovation is a recombinant search process, it is clear that we gain globally from lowering the barriers to entry.

There are other uncounted benefits of open sourcing. Tim O'Reilly, a supporter of the free software and open source movements, recently compared open source development to the "clothesline paradox" famous in alternative energy. The idea is simple: You put your clothes in the dryer, and the energy you use gets measured and counted. You hang your clothes on the clothesline, and it "disappears" from the economy. Value is created, but it's not measured and counted; it's captured somewhere else in the economy. Value capture and value creation are sometimes opposing forces. As seen in the recent financial crisis, extracting value can even come at the long-term peril of creation and economic wellbeing.

That economies effectively allocate resources to solve problems is not only one of the most robust findings of our century, it is also demonstrated by the very nature of our thought. As artificial intelligence researcher Eric Baum has noted, randomly generated computer code, when moderated by reinforcement learning inside an artificial economy, will reliably generate solutions to complex problems. The Western world has resoundingly and correctly convinced us that, when given the right operating environment, economies allocate resources more efficiently and spur innovation more regularly than centrally planned systems. However, we must be aware that, just as occurs in computer software experiments, economies optimize for efficiency only in the characteristics by which they are measured or constrained. We as humans must also interject our values in the form of appropriate constraints to achieve the outcome we desire. For example, in a capitalist system, supply chains become progressively more efficient through competition but, unlike the Internet, which was designed for fault tolerance, they do not become more robust unless they regularly experience the tragedy of disruption that governance is designed to avoid. We now are codependent with our tools.

These tools need to be as replicable, adaptable, and robust as we are, or we risk being separated from them. Given our increasing personal and geopolitical dependence on resources that stretch across vast regions and complicated dependencies, we would be wise to heed the fragility and complexity of our relationship with technology.

TECHNOLOGY AND US

Technology is the most powerful force shaping our world. The University of Oxford's Future of Humanity Institute and the newly formed Cambridge Centre for the Study of Existential Risk have been funded by innovators to study our complex relationship with technology. As Kevin Kelly, a cofounder of *Wired* magazine, points out in his book *What Technology Wants*, "Of all the animals we've domesticated, the most important animal we've domesticated is us."[4] We can think of technology as a seventh kingdom of life that we have created and on which we are now wholly dependent. According to Kelly, three-quarters of the energy produced is now used to feed technology. Kelly asserts that technology wants to become more complex and more specialized over time, but the question is whether we can be intentional rather than merely competitive in response to technological develop-

Figure 3. Incumbents access policy to increase barriers to entry over time

ment. If we are truly dependent on technology and need it in order to thrive, shouldn't we periodically refactor it to be more robust, more modular, and more freely available?

What is perhaps most incredible and inspiring is that any of us as normal citizens can freely download and carry around on a tiny USB key essentially all of our collective human knowledge. Examples include Wikipedia, Open Government data, Project Gutenberg's entire database of pre-copyright literature, a wealth of software tools, medical research, and the arXiv theoretical physics archive—the list goes on and will soon be longer. Open Source Ecology's contribution is to add the Civilization Starter Kit and its manufacturing capabilities to that list, and hopefully to the lives of the pioneering souls who will use, adapt, and improve it. All of this information—and I really mean all of it—can be taken anywhere at any time.

As industrial revolutions brought the world assembly lines and lifetime employment, the democratization of manufacturing signals a return to flexible self-employment. Moreover, in recent years we've noted the ease with which people can find and purchase what they want from micromanufacturers on Etsy, eBay, and other online shops. And one need look no further than Kickstarter to see how people vote with their dollars to promote particular values while at the same time having a direct connection and transparent interaction with a manufacturer/innovator. Eric von Hippel of MIT's Sloan School of Management defined the user-led innovation model in his book *Democratizing Innovation*. Among his conclusions is the insight that, as innovation becomes more user-centered, the information needs to flow more freely and in a more democratic way, thereby creating a "rich intellectual commons . . . [and] attacking a major structure of the social division of labor." Democratizing the means of production and making it accessible is an important way of improving the equity and distribution of material wealth, and it progressively reduces the level of material want and the need for welfare to maintain a harmonious society.

FOREIGN POLICY, SECURITY, AND RESILIENCY

As we have already mentioned, the nature of global supply chains creates foreign policy dependencies that historically have been problematic in times of conflict. It is extremely difficult to imagine what would happen to the availability of consumer goods if a significant conflict arose with China or another country that has an important manufacturing industry or critical natural resources. The United States no longer manufactures telephones, televisions, refrigerators, and many other items we think of as staples, but the manufacturing revolution promises to change that.

National governments currently have a limited set of tools to promote self-reliance, and the tools they do have are increasingly constrained by trade agreement and organizations such as the World Trade Organization. The United States has maintained its position as a net food exporter, but not all nations are so lucky. For example, after the collapse of the Soviet Union made gasoline and other foreign purchases impossible, Cuba was forced to pull elderly citizens out of nursing homes to teach the younger generations how to farm with oxen. Imagine what would happen if the developed world were asked to make this kind of transition! If democratizing manufacturing capability is important in providing protection against geopolitical disruption, it is essential in responding to natural disasters, pandemics, and other severe challenges on a global scale.

Distributive enterprise also represents an improvement in international aid. As our wisdom has matured on how best to provide aid to distressed agricultural economies, there is greater interest in "teaching a man to fish" through training and affordable user-serviceable tools. Howard Buffett in particular has pointed out the consequences of sending farm equipment from the developed world to Africa, where supply chains to support repairs are not available.[5] Hospital equipment sent to Afghanistan has met with similar criticism. Tools like the GVCS increasingly enable aid programs to provide both the materials and the training that will lead developing nations toward self-sufficiency.

For all its benefits, however, there are significant issues to consider in the local manufacturing revolution. Democratizing technology leads to more innovation and more fairness, but also more capability. In the United States, a man recently printed, in 3D, the critical lower receiver of an AR-15 assault rifle using freely

This OSE inspired art installation entitled "Amber Waves" was recently displayed at the 2012 Feast Conference. The rise in global food prices is plotted against global events such as the Arab Spring.

available CAD plans. This innovation reveals the ease with which such items can be produced and is cause for a rethinking of security policies.

LOOKING TOWARD THE FUTURE

Dystopian or utopian, equitable or inequitable, the future is impossible to predict. But while we can't say what the future will bring or what future technology is possible or even desirable, we can say that we want our civilization to have a robust and resilient core, and we want ourselves and our children to have adequate means not only to survive but to achieve material wealth. We can make that wealth more widely available and environmentally compatible at the same time we take intentional, practical steps to end material deprivation and conflicts over resources.

Factor e Farm is like a living science fiction novel, a combination of a return to roots and a futuristic vision. The community builds its own housing collectively, eats farm fresh eggs, and grows its own produce, which harkens back to America's agrarian society and values. All around the workshop, however, the industrial engines of production harken back to yet another area. This contrast is reflected perfectly as a community member wearing a flannel shirt bends down to update the software on an Arduino controller board. At Factor e Farm, generations of human progress has been condensed into the traditional values of cohabitation.

The ultimate results of the Factor e Farm's experiments and other related efforts can't be predicted, and we still have a long way to go to finish the 50 machines that will make up the OSE toolkit. The significance of the toolkit and how it will be used is as unclear as the future. Even now, the first large-scale replication of our equipment is under way on a sugar cane plantation in Guatemala. That operation is interested in adopting the OSE tools, and has made a plan to build housing for its workers using the compressed earth brick press. These developments are happening independently, which bodes well for the future.

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1. 'Open source tools' is a phrase used to mean a program—or tool—that performs a very specific task, in which the source code is openly published for use and/or modification from its original design, free of charge." Retrieved from http://www.webopedia.com/TERM/O/open_source_tools.html.
2. "Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments." Retrieved from http://www.arduino.cc/.
3. "The word Swadeshi derives from Sanskrit and is a conjunction of two Sanskrit words. Swa means 'self' or 'own,' and Desh means 'country,' so Swadesh would be 'own country' and Swadeshi, the adjectival form, would mean 'of one's own country,' but it could be loosely translated in most contexts as 'self-sufficiency.'" Retrieved from http://mettacenter.org/definitions/gloss-concepts/swadeshi/.
4. Kevin Kelly, *What Technology Wants.* New York: Penguin Books, 2011.
5. Howard is a grandson of Warren Buffett.

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