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TECHNOLOGY | GOVERNANCE | GLOBALIZATION

Special Edition for Tech4Society: A Celebration of Ashoka-Lemelson Fellows

Invention-Led Development

ENTREPRENEURIAL SOLUTIONS TO GLOBAL CHALLENGES

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Lead Essays

Cases Authored by Innovators

Special Edition for Tech4Society: A Celebration of Ashoka-Lemelson Fellows

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. Cases authored by innovators. 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. Following each case narrative, we present commentary by an academic discussant. The discussant highlights the aspects of the innovation that are analytically most interesting, have the most significant implications for policy, and/or best illustrate reciprocal relationships between technology and governance.

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.

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Julia Novy-Hildesley

By the Grace of Invention
How Individuals Power Development

> We live only by the grace of invention: not merely by such invention as has already been made, but by our hope of new and as yet non-existing inventions for the future.
>
> —Norbert Wiener, *Invention: The Care and Feeding of Ideas*

Invention and innovation are critical drivers of prosperity. They hold the potential to eradicate poverty and support sustainable development, yet their importance is often overlooked. Currently, we are failing to engage the global community systematically and inclusively in innovation, and thus are likely missing opportunities for breakthroughs that could address the most pressing issues facing humankind.

Start with global development. There, the center of gravity of the debate among experts has been on the effectiveness of international aid, or lack thereof. Thought leaders such as Jeffrey Sachs of Columbia argue that meeting the challenge of inclusion in global development will only be possible through dramatic increases in direct foreign assistance. Aid skeptics such as William Easterly of New York University and Dambisa Moyo, a Zambian economist, point out that there is virtually no correlation between aid and GDP growth. Nicholas Kristof of the *New York Times* recently moved the debate in the right direction when he argued that we should discuss how best to achieve development, rather than debate whether or not international aid works.[1]

In fact, the process of development is not as mysterious as it is often made out to be. Human development happens whenever people have the skills to invent, the resources to innovate, and the opportunity to grow their ventures. Unleashing the creative potential of individuals, in turn, is also not a fundamentally complicated matter. Give most people some empty space, rudimentary tools of expression, and the permission to create something new, and they will waste little time filling in the blank canvas. Inventiveness is an essential human characteristic—fully realized in few, but available to all.

Julia Novy-Hildesley is executive director of the Lemelson Foundation.

Human ingenuity is not only our most valuable natural resource, it is also our most abundant. People are entrepreneurial by nature, particularly when it comes to helping themselves and their families overcome difficult situations. The entrepreneurial model of development, driven by humanity's nearly limitless capacity for invention and innovation, is the only one that is proven, and it is the only one that can be scaled to meet the challenge of economic inclusion at a global scale. Even if aid can be made effective, it cannot be made to scale. The levels advocated for by Sachs in *The End to Poverty*, and by others since, are both inadequate and fundamentally unsustainable. Instead, we must turn our attention to discovering what government, the private sector, and civil society can do to create an enabling environment where individual creativity and entrepreneurship can thrive, where people are empowered to lift themselves out of poverty.[2]

Human ingenuity is not only our most valuable natural resource, it is also our most abundant.

This new approach is not just about growth in developing countries; it is relevant to the challenge of development everywhere. All countries struggle with social injustice and economic volatility. As globalization proceeds, development challenges become more interconnected, with difficulties in one region creating instability in another. Conversely, creating an environment conducive to invention, innovation, and entrepreneurship in one location can create positive ripple effects elsewhere, leading to a virtuous cycle of global development. Recent discussions about global security have built on this logic, with many arguing that clean energy innovations will increase energy independence and reduce conflict, or that supporting innovation and opportunities for self-determination in poor countries can lessen the effects of fundamentalist extremism.

In this essay, I advocate for an approach to development that derives from five fundamental tenets:

- Shifting our focus to individuals and their potential—thinking of all people as inventors, innovators, and entrepreneurs
- Embracing a bottom-up, demand-driven view of the world, where people design solutions, and government's role is to create an enabling environment for them to do so
- Emphasizing business principles, recognizing that the best ideas must reach enormous scale in order to combat global poverty and achieve sustainable development
- Insisting upon linking evaluation criteria with evidence of effectiveness—will a program or investment enable a larger pool of people to more fully unlock their potential? And is the focus of their innovation directed toward advancing sustainable development in a scalable way?

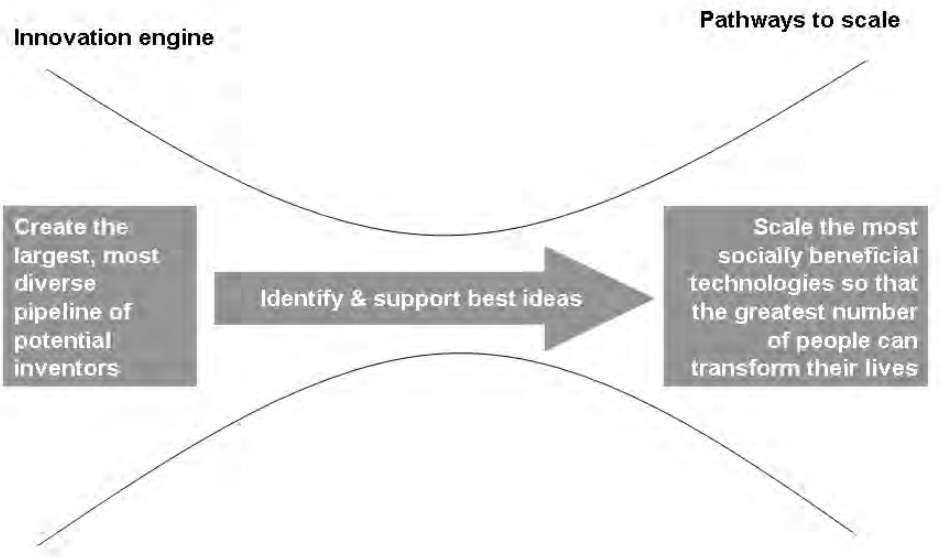

Figure 1. Driving Development by Enabling Invention, Innovation, and Entrepreneurship

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- Taking a forward-looking approach, focusing less on bailouts and much more on start-ups

For the past 15 years, the Lemelson Foundation has experimented with strategies and programs to implement this approach with its partners. The organization promotes a focus on two dimensions: (1) building an innovation engine—a diverse pipeline of future inventors, and (2) creating pathways to scale (see Figure 1).

This essay introduces both concepts and shares what we've learned. The essay is organized into four parts. Following this introduction, I discuss ways to increase the number and diversity of inventors. I then explore pathways to scale, emphasizing the importance of business model innovation and social enterprise investment to extend the benefits of the innovation engine. I conclude with some thoughts on the roles that governments, philanthropists, NGOs, and the private sector play in implementing this new approach to development.

THE INNOVATION ENGINE

At its core, the innovation engine is about harnessing the full potential of human creativity. To be effective, the engine must be large, diverse, and highly efficient. We need large numbers of innovators to guide us in the 21st century. We must also recognize that good ideas may come from anywhere and from anyone, not just corporate labs or Silicon Valley. Finally, the engine should be designed to generate as many breakthroughs as possible.

The Lemelson Foundation's approach to creating and nurturing a global innovation engine has three pillars:

- Engaging youth in science and engineering education programs, which help nurture a large pool of future innovators
- Working to ensure that education programs attract and retain a diverse population of young people so that the innovation engine will generate much richer and more relevant ideas, and
- Focusing on collaboration to improve the engine's efficiency

Engaging Youth in Science and Engineering

Many countries are seeing participation rates in technical fields decline. In the United States, for example, among the more than 1.1 million seniors in the class of 2009 who took the ACT Assessment college entrance and placement exam, fewer than 6% planned to study engineering in college, down from nearly 9% in 1992. In addition, these students are less certain of their major than those in the past, with more than 40% indicating they need help deciding on their educational and career plans.[3] As President Obama noted on *The Jay Leno Show* in 2009, we want our brightest students coming out of university to want to become scientists and engineers, not investment bankers.

Research indicates that in order to expand the pool of tomorrow's inventors, we must focus on early intervention, out-of-school programs, and generating perceptions of engineering as fun, collaborative, and relevant to making a difference in the world. A study of Nobel laureates in the sciences documents that 75% were inspired by early experiences outside of school, while other studies report that teaching invention to young children generates tangible results, including new technologies and increased interest in technical fields.[4]

The Lemelson Foundation has launched and supported a variety of programs that seek to inspire and mentor youth in invention and technical fields. The Lemelson-MIT Program awards the world's largest cash prize for invention, as well as mid-career and student prizes. It hosts an online resource guide for inventors and supports high school InvenTeams that work to tackle problems in their communities. Similarly, Ashoka's Youth Venture program engages teenagers from developed and developing countries in invention and entrepreneurship projects and team challenges, offering prizes to reward and showcase the most creative ideas.

Public television, media and government initiatives also have significant influence. WGBH-Boston developed a public television show called *Design Squad* that inspires teenagers to invent, by showcasing real-time invention challenges tackled by teams of fun-loving, creative youth. *Design Squad* is hosted by a peer role model, the charismatic Nate Ball, a former Lemelson-MIT student prize winner. Hands-on exhibits at museums can also inspire young people. For example, the Lemelson Center for the Study of Invention and Innovation at the Smithsonian Institution[5] attracts hundreds of thousands of visitors each year to Spark!Lab, where children do hands-on invention experiments. President Obama's Educate to Innovate program, including a national science fair and laboratory day, has helped

elevate the stature of this issue and has increased investment by private corporations in science and engineering education.

Finally, in-school programs that support science, technology, engineering, and math (STEM) are essential. The Gates Foundation and many other organizations are striving to improve the quality of, and diversity represented in, STEM fields by focusing on education strategies validated by research.[6] National governments must complement private-sector efforts by highlighting the importance of STEM and strengthening education. Consider the impact that Jawaharal Nehru, India's first prime minister, had with his vision that the Indian engineer would drive the development of the newly independent nation, through the design of communications infrastructure, power systems, roads, dams, and drinking water facilities. In the decades following his announcement, the government established a national network of Indian Institutes of Technology (IITs), now some of the most respected engineering universities in the world. These IITs, and a host of other regional engineering universities, collectively graduate over 500,000 new engineers each year.[7]

Increasing the Diversity of Innovators

The innovation engine is most effective when it taps into everyone's potential. We need strategies to attract and nurture girls, minorities, and developing-country innovators in science and technology fields. Without an explicit focus on this, we will continue to miss out on the creative potential of well over half the population.[8]

Encouraging Female and Minority Participation

Research indicates that children of both genders and diverse backgrounds respond to invention education by demonstrating increased inventiveness.[9] Studies confirm that programs designed specifically to engage women and non-majority individuals are effective in spurring inventive capacity.[10] In order to increase participation rates of girls and minorities, the Lemelson Foundation has designed and supported longer-term mentoring programs that deepen students' exposure and proficiency in STEM fields.

One partner, MESA (Math Engineering Science Achievement), engages girls and minorities by creating collaborative student teams that tackle multiple invention challenges over a period of several years. This creates a supportive and intensive opportunity to build technical skills. Shay Schlafle, a13-year-old African American girl, illustrates the impact of MESA. Shay was born with brittle bone disease, is sometimes confined to a wheelchair, and can easily break a bone by walking too much. After two years as a MESA student, Shay competed with three female teammates in an 8th grade MESA competition to design a trebuchet, a catapult-like device. Despite coming from an underperforming school, Shay's team won the state competition based on the distance and accuracy with which their trebuchet could hurl objects through the air. This success changed Shay's vision for the future. While her mother did not attend college and Shay did not intend to pursue higher education, she now plans to go to college and study engineering.

Relative to their peers in public schools, MESA students demonstrate higher high school and college graduation rates, as well as greater rates of participation in STEM studies at the postsecondary level.[11] Another partner, the Saturday Academy, offers summer internships at local science and engineering firms and provides a stipend (greater than the pay from a minimum-wage job) to remove barriers to participation by underserved minority students.[12] To test a new mentoring strategy, the Lemelson Foundation launched Mentors for Young Inventors, with WGBH-Boston. The program pairs minority engineers in high schools with college student and professional engineers of the same ethnic background to support them through a multiyear, out-of-school engineering program.

Many programs have emerged at the international level. For example, the Institute of Electrical and Electronics Engineers (IEEE), which has more than 365,000 members in approximately 150 countries, brings together students, professionals, academics, and industry leaders to share ideas and present research findings. The organization also offers prizes to the best engineers and houses an exhibition for student and professional inventions.

So that programs can be improved continuously, governments should continue to fund research that helps us understand the key reasons why girls and minorities do not participate fully in science and technology. In the United States, the American Association for the Advancement of Science (AAAS), the National Science Foundation (NSF), and the National Academies of Engineering (NAE) are supporting such research.

Inventor Initiatives in Developing Countries

There is also a tremendous opportunity to benefit from the creativity of innovators in developing countries. Providing tailored and catalytic support to individuals engaged in technological innovation in developing countries could both increase the level of innovation globally and improve the relevance of technologies for poor people. Imagine how many Einsteins are born in Africa, but lack access to the education, tools, and resources they need to realize their full potential. Because the ideas developed by innovators in developing countries are more likely to focus on pressing local issues, engaging these inventors is a way to make sure that the full range and complexity of global challenges is addressed.

In developing countries, educated and uneducated innovators alike have demonstrated their innovative capacity. In Malawi, 14-year-old William Kamkwamba had to quit school because his parents could not afford $80/year to send him. But poor farm yields and a food crisis inspired him to invent his way out of poverty. Using an old textbook from a local library and parts from bicycles and tractors, William built a 16-foot-tall, 12-watt windmill to generate electricity and pump water on his family's farm. He has since published a book and become a spokesperson for the importance of supporting local innovators in developing countries.

Dr. Sathya Jeganathan, a doctor from the Chengalpattu hospital in rural India, provides another example. She invented a low-cost baby warmer and had it built by local craftsmen. The invention has cut the neonatal mortality rate at her hospital in half. With help from the Lemelson Recognition and Mentoring Program (RAMP) in Chennai,[13] Dr. Jeganathan intends to refine the design and apply for the certification she needs to distribute it throughout the Indian government's health system and perhaps beyond.

As Mukesh Ambani, CEO of Reliance Industries, India's largest company, stated recently, "I am quite clear that 20 years from now, we would not talk about garages in Silicon Valley. We will talk about projects in the villages and rural areas in India, which are then scaled all over the world."[14] The Honey Bee Network has documented over 100,000 grassroots innovations in India alone. The Ashoka-Lemelson Fellows Program has identified and supported over 100 inventor-entrepreneurs, largely from developing countries, who have launched successful social enterprises in the areas of clean energy, mobile technology, and water and sanitation, among others.

While the literature is thin, there is an ever-growing body of evidence on how to nurture local innovators in developing countries. The Appropriate Infrastructure Development Group (AIDG) provides workshop space and business support to rural, uneducated engineers and entrepreneurs in Central America. In contrast, Stanford-India BioDesign targets professional doctors in India, leveraging international universities and intensive training to spur the invention of biomedical technologies that serve Indians. The Lemelson RAMPs in India, Indonesia and Peru work with national universities and local non-profits to design mentoring and financing plans for competitively selected local innovators working on sustainable development. The university partners offer prototyping facilities, technology validation and access to networks. Non-profit partners provide business development support and help negotiate intellectual property and licensing agreements.

A group of these organizations meets annually with incubators from industrialized countries to share best practices and replicate successful approaches. Examples are the Santa Clara University Global Social Benefit Incubator Program, the Design that Matters Program of MIT, and the National Collegiate Inventors and Innovators Alliance.

Companies based in developing countries are also working to harness the potential of in-country engineers to develop new products highly adapted to local conditions. A recent *Wall Street Journal* article describes a shift in focus among Indian firms, from serving Western companies to providing meaningful products to India's 1.1 billion people.[15] Mumbai's Godrej & Boyce Manufacturing Company (known for a range of products from padlocks to pest management) developed a low-cost refrigerator called the Little Cool. It sells for $70 and runs on a cooling chip rather than a noisy, breakable compressor. The unit uses high-end insulation to stay cool for hours without power, is portable for use by migrant workers, con-

sumes half the power of rival low-end refrigerators, and has only 20 parts (as compared to the usual 200).

The article also notes that the growing awareness of this new market has sparked new business divisions within established Indian companies. To develop its tiny $2,200 Nano car, for example, Tata Motors employed a division of nearly 300 engineers over four years. The group rethought all aspects of the development process, from design, to manufacturing, to distribution and financing.

Fueling New Discoveries Through Multi-Disciplinary and Cross-Cultural Collaboration

Engaging a large and diverse pool of innovators is necessary, but insufficient, to create a highly efficient innovation engine. Evidence suggests that fostering collaboration can accelerate invention and innovation outcomes.[16]

The Lemelson Foundation has created several programs to experiment with this approach. In 1995, Jerome Lemelson created the National Collegiate Inventors and Innovators Alliance (NCIIA), modeled after the successful National Inventors Council (NIC) that was launched in 1940 during World War II.[17] The NCIIA funds courses and multidisciplinary student teams in the fields of technological innovation and entrepreneurship. It has yielded 48 patents and 55 start-up companies through its $5.1 million investment in 347 student collaborations. This appears to be more efficient than most angel investors and university tech transfer offices, although it is difficult to do direct comparisons.[18]

An evaluation of the NCIIA grants program for the years 1997 to 2005 reported that 17 "high-impact" grants produced the following outcomes:

- $40 million in new investment for student start-ups
- Creation of at least 700 jobs locally, and
- An estimated $35 million annually in regional economic impact[19]

The Lemelson Foundation has helped launch new programs at the NCIIA and the Massachusetts Institute of Technology to foster cross-cultural teams of students and faculty. These programs and others have demonstrated exciting results when diaspora students and faculty, and their colleagues, partner with communities in the developing world. NCIIA's Sustainable Vision program has resulted in a new device to test for counterfeit pharmaceuticals in developing countries. MIT's International Development Initiative has yielded a soy milk maker for an orphanage in Peru, a chlorinator for community water systems in Honduras, and a portable solar cooker for the Himalayas.[20] Local innovators have a deep understanding of local needs and of the sociocultural context. University experts can offer new perspectives on engineering, materials, and design principles, as well as connections to investors and distribution systems.

The Ashoka-Lemelson Fellows Program also enhances innovation through cross-cultural collaboration. The program identifies early- to mid-career innovators from industrialized and developing countries, offers a stipend, and connects fellows to professional networks, including other fellows. Joseph Adelegan, an

Ashoka-Lemelson Fellow from Nigeria, collaborated with researchers at the Biogas Technology Research Centre in Bangkok, Thailand, as he designed a fixed-filter anaerobic biogas converter that could remove slaughterhouse effluents from air and water. David Kuria, a Fellow in Kenya, is working with the University of Colorado to refine his business model. David has launched technology-enabled sanitation "kiosks," transforming run-down toilet stations in Kenya into mini shopping malls where customers can even get their shoes shined. Customers can use mobile phone technology to pay for using the toilets and other services.

Beyond civil society collaborations, there is a growing movement to partner with the private sector to spur innovation for global development. To increase the momentum of this movement, the Lemelson Foundation funded the "Design for the Other 90%" exhibit in 2007,[21] initiated by Paul Polak of IDE and developed by the Smithsonian's Cooper-Hewitt National Design Museum. The exhibit challenges us to reverse the current situation in which most of the world's cleverest designers cater to the richest 10% of consumers, designing haute couture clothing, Maseratis, and elegant cell phone cases—while people around the world are waiting for $2 eyeglasses, $10 solar lanterns, and $100 houses. The exhibit offers a glimpse of what could be achieved if the industrialized world's professional design community focused on the challenges of eradicating poverty and conserving the environment.

Many designers are responding to this challenge. Idealab, a solar technology innovator in San Francisco, designed a low-cost solar home-lighting system for families living off the grid. Idealab reached out to the Lemelson Foundation's network of clean energy entrepreneurs in developing countries—such as SELCO, IDEAAS, and Emergence Bioenergy. After collaborating to learn about local markets, customer preferences, and their ability to pay, Idealab dramatically changed its technology design and began field-testing with India-based SELCO, drawing on SELCO's in-country experience.

Transnational firms are also beginning to engage their design teams in cross-cultural collaboration. Recently,some of the best designers at Philips,the multinational electronics company, worked in rural India with local nongovernmental organizations, self-help groups, and local industrial entrepreneurs. Together, they developed an affordable,low-smoke solution for healthy and safe cooking that fit the sociocultural and infrastructural conditions. The intellectual property and design was donated to local stakeholders and the company is working with Indian partners to establish a self-sustaining distribution model for the stove.[22] The Leap Frog Fund, a joint initiative of the Schwab and Lemelson foundations, has shown that these exchanges are particularly effective when the "exporting" innovators work with "importing" entrepreneurs to support the integration of the technology or innovation in the new setting.[23]

After a recent visit to Asia, Jeffrey Immelt, chairman and CEO of General Electric, brought attention to another dimension of cross-cultural collaboration: reverse innovation. "Most American multinationals go through stages of globalization where you export, start to localize, and ultimately get to the point where you

build local capability. And then you can start transporting ideas back to the developed world."[24] Many ideas have already been successfully transferred. For example, bus rapid transit systems developed in Curitiba, Brazil, were transferred first to Bogota, Colombia, and more recently to cities in the United States, including Los Angeles, Cleveland, Boston, and Eugene. Treatments derived from medicinal plants have been identified in developing countries, and then developed into pharmaceuticals in the industrialized world.

While these types of experiments are gaining momentum, we must work to make these collaborations more systematic and scalable. Technology Development Centers, such as those designed by KickStart in Kenya, and IDE and SELCO in India, root innovation in local contexts and make use of developing-country facilities and engineers, while providing national and international connections. These centers are logical hubs for cross-cultural collaboration and hold the potential to accelerate technological innovation for development. By failing small but learning big and tapping the "wisdom of the hive," we can generate the collective learning necessary to rapidly evolve a range of viable strategies and models.[25]

PATHWAYS TO SCALE

A robust pipeline of future inventors will take us part way, but in order to eradicate poverty and build sustainable economies, we must create pathways to scale for key innovations. The innovation engine's greatest technologies will have the potential to improve lives and help individuals reach their full potential. They will generate income by serving as tools that enable people to lift themselves out of poverty, thus increasing self-determination and global participation. Finally, the greatest innovations will enhance, rather than deplete, the environment and natural resource base on which we depend.

Twenty-first century sustainable products are needed in both industrialized and developing countries. Bringing such technologies to scale requires three elements: (1) creating an enabling environment for their production and adoption; (2) building appropriate business models for their dissemination; and (3) driving large-scale investment to those social enterprises. In rich countries, because the business and investment environment is generally strong, the focus should be on creating incentives for the design, mass manufacturing, and purchasing of sustainable technologies. Where there is political will, scaling such technologies is relatively straightforward. Consider Germany's success creating jobs and generating clean energy on a vast scale as a direct result of strategic and consistent investments in solar technology.

In contrast, in developing countries, all three elements require attention. Peruvian economist Hernando de Soto and MIT economist Daron Acemoglu document the primary importance of building the rule of law, formalizing land tenure and intellectual property rights, and creating a "governing system that offers opportunities to achieve and innovate."[26] In addition to political will and a strong enabling environment, we need radically different business models to reach the

five billion people living on less than $10 a day. As these innovative enterprises emerge and become proven, we must then drive greater investment to them. Because the literature on strengthening enabling environments is quite rich, this section describes business model innovations and investment strategies that help launch and grow successful enterprises.

Business Model Innovation

The most innovative businesses will engage customers and help build a middle class from the bottom up by innovating across four dimensions: design, marketing, distribution, and finance. But we don't yet know which approaches will scale up most effectively. As with seeding collaboration to improve the innovation engine's efficiency, we must increase the number of business model experiments and the speed with which knowledge is transferred between them in order to reach scale. To do this, the Lemelson Foundation and many others are investing in for-profit and nonprofit social enterprises working in developing countries across these four dimensions.

Design

The Lemelson Foundation has invested in and learned from several pioneers in the field of affordable design. International Development Enterprises (IDE), a nonprofit working in Asia, Africa, and Latin America, focuses on ways to design around various cost drivers. IDE makes two trade-offs: exchanging capital for labor (as labor is abundant in most poor countries) and quality for affordability. For example, during the design process for its drip irrigation kits, IDE reduced the amount of plastics needed by thinning the pipe. This reduced system pressure by 80%, requiring hands-on management from farmers to run the systems.[27] Nonetheless, it brought the IDE product within the price range of farmers with less than one-sixteenth of an acre of land. IDE's approach allows customers to "get on the technology ladder," make money, and then move on to a superior model once they can afford it.

In regions with dispersed populations and few shops to provide service and spare parts, products must be designed with minimal maintenance requirements. Because of such conditions, Kenya-based KickStart[28] has invented a range of irrigation pumps that are highly robust. KickStart's pumps are stronger, but more expensive, than IDE pumps.

Like the agriculture sector, the health sector tends to generate products that are beyond the reach of poor consumers. Conversion Sound (CS), a U.S.-based for-profit social enterprise, worked to rethink hearing aid design. Its prototype costs one-tenth the industry standard ($77 vs. $800). By drawing on lessons from the consumer electronics industry, CS has also reduced—by 96%—the cost of equipment for fitting hearing devices. CS employs simple hand-held wireless systems to measure hearing capabilities, enabling village-trained health workers, who are much more cost effective than doctors, to provide testing services. CS has also

designed a low-cost device that fits hearing aid molds on the spot, obviating the need for multiple visits.

Marketing

Once design challenges are overcome, social entrepreneurs must convince customers with severely limited resources to invest in their 21st-century sustainable products. Lemelson Foundation partners have had particular success using product demonstrations and public media to engage customers.

In Kenya, KickStart attends agricultural fairs where it sponsors water-pumping contests among farmers to build awareness of its products. Winning farmers return home with new treadle pumps. Retailers and distributors use the fairs to create customer awareness through local language flyers, and potential customers can provide contact information, enabling retailers to follow up with them after the event. In rural India, IDE broadcasts local music from traveling vans to attract potential customers. Staff members then set up demonstrations of IDE's agricultural technologies, such as micro-drip systems, sprinklers, and treadle pumps.

The most creative organizations use radio, film, and music to promote new technologies. In India, for example, IDE developed a feature-length Bollywood film of a couple whose marriage was saved by the income generated from a treadle pump. Millions of rural Bangladeshis viewed this film, leading to the sale of over one million treadle pumps in the region.[29] In Kenya, the Maasai rap artist, Mr. Ebbo, recorded a song and video for KickStart to tell the story of treadle pumps ending the poverty of African farmers. It was broadcast throughout East Africa and helped KickStart reach hundreds of thousands of new potential customers.[30]

Distribution

Design and marketing are parts of the puzzle, but distribution is also a major challenge. The Lemelson Foundation's partners have developed creative strategies to diffuse their innovations through community-based partners, the local private sector, and government.

Distribution through community partners accelerates the diffusion of products, because it enables social enterprises to operate in a highly decentralized way, informed by local knowledge. Conversion Sound plans to use thousands of community-based health entrepreneurs to distribute its low-cost hearing aids. This will enable CS to expand distribution rapidly because it will not be limited by the shortage of government-run health clinics in remote areas. As CS founder David Green says, "Our distribution concept is disruptive since the product can be distributed outside the existing exclusive hearing aid distribution channels, which have a pricing system and mentality that is often the primary bottleneck for reaching the hard of hearing client in an accessible and affordable manner."[31]

SELCO has decentralized distribution by engaging unemployed youth in Indian villages to market and sell its solar home-lighting systems on commission. To expand SELCO's distribution, the Lemelson Foundation supported a partner-

ship between SELCO and SEWA (the Self-Employed Women's Association), an established community-based organization in India. SELCO trains SEWA members to become "clean energy entrepreneurs." In turn, these entrepreneurs sell SELCO's clean energy technologies to SEWA's 700,000 members. Similarly, Grameen Phone (GP) relies on the Grameen Bank, a community-based microfinance institution in Bangladesh, to select entrepreneurs for GP's "village phone" model. Grameen Bank identifies women with strong loan repayment histories who then purchase a cell phone (often using a loan from Grameen Bank) and provide a shared phone service to fellow villagers for a small fee.

Interestingly, transnational corporations are also forming partnerships with community-based organizations. In India, Hindustan Unilever has leveraged over one million village women through self-help groups to become low-cost distributors of Unilever products.[32]

The local private sector is another powerful distribution resource. Across the developing world, millions of village shops provide customers with basic foods, paint, building materials, seeds, and more. Social enterprises partner with shop owners, adding their products to the shelves. KickStart and IDE, for example, distribute most of their products through such shops, which can also provide access to replacement parts and repair services. They also provide a method of capturing customer feedback, which enables social enterprises to address design, marketing, maintenance, or financing concerns quickly.

Finally, some organizations piggyback on government distribution channels. This can be particularly relevant for health technologies. After designing a low-cost single-injection device called Uniject, PATH (the Program for Appropriate Technologies in Health) partnered with the Indonesian government. The national health system trained 60,000 village midwives (one for every village in the nation) who then administered over 40 million doses of Hepatitis B vaccine to newborns.[33] PATH is now working with several countries to test the viability of using Uniject to administer oxytocin to women in the third stage of labor, thus minimizing postpartum hemorrhage, a leading cause of death for women in developing countries.[34]

Finance

For-profit and nonprofit social enterprises must bring their products within reach of poor customers. Sometimes this requires helping customers access finance. Other times, it calls for leasing arrangements or innovative pricing strategies.

SELCO brought its $400 solar home lighting solutions within reach of customers by working with banks and microfinance institutions. SELCO encouraged them to lend to poor customers by working with bank loan officers to help them understand the productivity that often follows the adoption of solar products. The training helped unlock loans, but interest rates were still high. To jumpstart the market, SELCO bought down the rates and covered a portion of the downpayments for early adopters.

IDEAAS, a nonprofit provider of solar energy in Brazil, took another approach. The organization offers leasing arrangements to compensate for the lack of microfinance in regions where it works. This enables customers in remote Amazonia to afford solar home-lighting systems by paying a low monthly fee.[35]

Other organizations have innovated tiered pricing models to increase access to technologies. This approach enables the poorest customers to get products and services for free, while the enterprise as a whole earns a healthy profit. David Green, the founder of Conversion Sound, has coined this "compassionate capitalism." Conversion Sound employs tiered pricing to complement its many other cost-cutting measures. Cross subsidies from profits derived from well-to-do clients lower the prices for the poorest customers. Similarly, the Aravind Eye Hospital in India performs 70% of its cataract surgeries for free or below cost, and 30% at market rates.[36] It offers the same doctors, procedures, and equipment to all patients, but higher-paying customers have access to a more comfortable and quiet waiting room and to private overnight rooms. This seems to be sufficient to drive self-selection to the different pricing options.

Finally, organizations may employ a hybrid structure, where a for-profit arm supports the mission of a nonprofit social enterprise. The nonprofit World Bike manufactures and sells cargo-carrying bicycles in East Africa at a very low cost, while its for-profit arm generates a surplus by selling similar bicycles as "sports utility bikes" (SUBs) to bicycle tourists at a higher price.

Driving Investments in Social Enterprises

All of these innovations help poor customers access life-changing technologies. Technology entrepreneurs serving these "base of the pyramid" customers also need financing to launch and grow their businesses. Currently, many such enterprises are stuck in a "missing middle" where they cannot access capital. The loans available from the microfinance institutions that serve their customers are far too small, and the scale of private equity investments available to large firms exceeds the absorptive capacity of these businesses.

The Aspen Network of Development Entrepreneurs (ANDE) was created to fill this gap. Collectively, ANDE members represent over $750 million in investment capital directed toward small and growing enterprises in developing countries, which need investments in the range of $25,000 to $2 million.[37]

ANDE members provide loans, equity investments, and technical assistance to businesses that are not being served by local banks because they are perceived to be too risky. One ANDE member, E+Co,[38] finances new solar energy enterprises serving rural Tanzanians. Local banks are not interested in such start-ups. E+Co also provides business development training, making the new entrepreneurs more likely to succeed. On a larger scale, the Gates Foundation awarded a $10 million loan and $5 million grant to Root Capital,[39] another ANDE member, will extend financing and training to 500,000 farmers and producers in Sub-Saharan Africa as a result of a new $10 million loan and $5 million grant from the Gates Foundation.

These businesses also need funds for inventory and capital equipment. In tough economic climates, banks are particularly hesitant to offer credit lines to new businesses or small companies. The United States Agency for International Development (USAID) and the International Finance Corporation (IFC) have successfully used loan guarantees to create incentives for local banks to make such funds available.

The Lemelson Foundation employs a similar technique: "first-loss" capital. It used this tool to facilitate access to inventory financing for D.light Design, a producer of affordable, solar-powered LED lanterns. While D.light had raised significant equity and had orders on its books, it couldn't access a credit line because it was perceived as a high-risk start-up. After the Lemelson Foundation provided a first-loss loan to the Calvert Social Investment Fund (CSIF), CSIF financed D.light, offering twice the amount of the Foundation's loan because of the risk reduction provided by the Foundation. The relationship with Calvert enables D.light to establish a credit history with a lender (rather than a foundation), potentially enabling the company to secure a larger line of credit from banks in the future.

With continued efforts from governments, foundations, and nonprofit organizations to "buy down" the risk for banks, private capital flows to start-ups and small businesses are likely to increase. There is a new world on the horizon, in which local banks open dialogue with small enterprises and individual loan officers become less risk averse. We are seeing the emergence of local financial intermediaries in developing countries that are helping small businesses develop the financial controls and systems required by the banks, so they are more likely to qualify for loans and other investments. Eventually, we may even see a new, more patient form of venture capital emerge. This will be necessary to reach the kind of scale we need to support social enterprise models. Government and foundation investment will be dwarfed by the resources of the private sector, should we be able to harness it in the direction of small business experiments.

CONCLUSION

We find ourselves at a turning point in human history. We know that development is driven by technological progress. Rich countries have experienced substantial benefits since the Industrial Revolution—electricity and vaccines, computers and the Internet, to name a few. But we are also living with unsustainable practices. Five billion people are not participating in the global economy. Some of the technologies that drove development in the rich world have had negative environmental and social consequences.

Two primary obstacles impede our progress. We have failed to build an efficient and inclusive innovation engine focused on the triple bottom line. And we have failed to create pathways to scale for the sustainable breakthroughs that are generated. All sectors must play their part in overcoming these barriers. Governments must invest in education and build enabling environments that foster invention, innovation, and entrepreneurship. Social enterprises must increase

their efforts to innovate ways to serve the more than five billion people excluded from participation in the global economy. The private sector must harness its design, marketing, distribution, and financing capacity toward this same end. And foundations must continue to take risks, backing new ideas with great potential.

We have had a glimpse of this opportunity through leapfrogging mobile technologies, clean energy innovations, and child and maternal health products. Now we must extend this vision globally, and to every individual. Thomas Friedman of the *New York Times* recently described the need to incubate 10,000 inventors in 10,000 garages to fuel American economic recovery. Stuart Hart of Cornell University echoes Friedman in his article "The Green Leap." He advocates incubating "thousands of small-scale, yet radical business experiments aimed at leapfrogging today's unsustainable practices, each with the opportunity to grow and become one of tomorrow's sustainable corporations." [40] By focusing explicitly on cultivating human ingenuity, we have an opportunity to transform development. With a strong innovation engine and all actors focused on enabling and supporting pathways to scale, we will unleash the power of invention and entrepreneurship to create sustainable solutions to the great challenges ahead.

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This essay stems from the wisdom of Jerome Lemelson, founder of the Lemelson Foundation and one of the most prolific inventors in U.S. history (with over 600 patents). Jerome Lemelson articulated the need to focus on invention and entrepreneurship to advance development more than thirty years ago, long before the global community embraced such ideas. It also emerges from the leadership of Dorothy, Eric, and Robert Lemelson, Susan Morse and Jennifer Bruml, the family of Jerome Lemelson and the Board members of the Lemelson Foundation. Their clear vision and whole-hearted embrace of creativity has given life to the many experiments I have described here. I am grateful to my bright, creative, and committed colleagues at the Foundation. Without them and the brilliant and inspiring funded partners ("grantees") with whom we have the privilege to work and learn from, I would not have written this essay.

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indicates that in 2007, $48.8 billion was invested in university research, yielding 3,622 patents and 555 start-up companies. Hence, each patent cost $13 million on average and each start-up $88 million, as compared to the NCIIA results of $106,000 and $92,000, respectively. This huge discrepancy is somewhat misleading, however, as not all research dollars were intended directly for innovations with commercial application, whereas the NCIIA grants were specifically for this purpose. Nonetheless, it indicates what could be achieved by an explicit focus on translating research into commercial application.

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