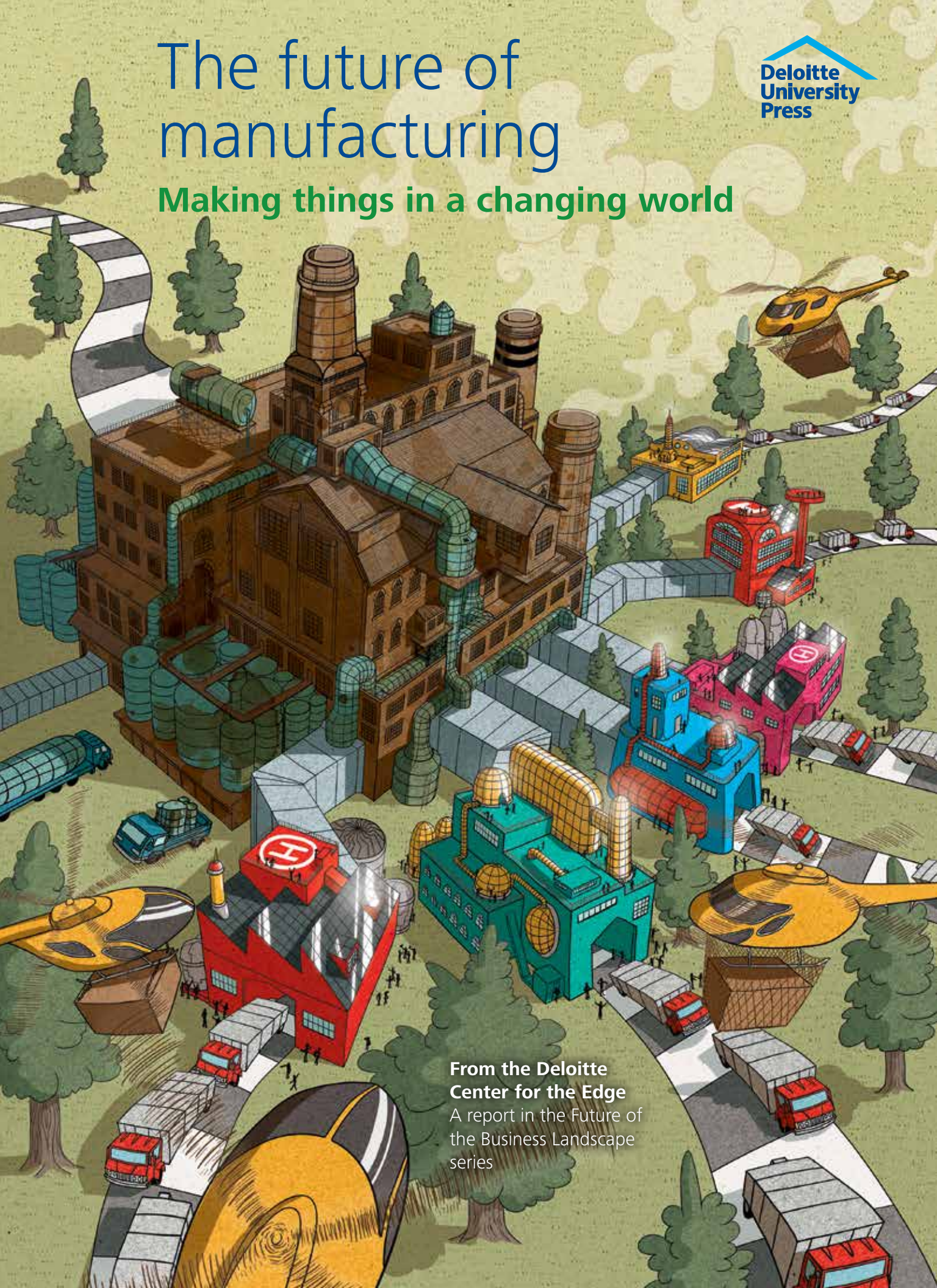
The future of manufacturing

Making things in a changing world



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About the authors

John Hagel III (co-chairman, Deloitte Center for the Edge), of Deloitte Consulting LLP, has nearly 30 years of experience as a management consultant, author, speaker, and entrepreneur, and has helped companies improve performance by applying technology to reshape business strategies. In addition to holding significant positions at leading consulting firms and companies throughout his career, Hagel is the author of bestselling business books such as *Net Gain, Net Worth, Out of the Box, The Only Sustainable Edge,* and *The Power of Pull*.

John Seely Brown (JSB) (independent co-chairman, Deloitte Center for the Edge) is a prolific writer, speaker, and educator. In addition to his work with the Center for the Edge, JSB is adviser to the provost and a visiting scholar at the University of Southern California. This position followed a lengthy tenure at Xerox Corporation, where JSB was chief scientist and director of the Xerox Palo Alto Research Center. JSB has published more than 100 papers in scientific journals and authored or co-authored seven books, including *The Social Life of Information, The Only Sustainable Edge, The Power of Pull*, and *A New Culture of Learning*.

Duleesha Kulasooriya (head of strategy, Deloitte Center for the Edge) leads the development of the Center's ecosystem and contributes to core research exploring the edges of business and technology. Over the past few years, he has explored how the world is changing in very dramatic ways as a result of ever-evolving digital infrastructure and liberalizing public policy, as well as the implications for individuals and institutions. Kulasooriya led the team that developed and authored the inaugural Shift Index report and has written and spoken extensively on the use of new technologies to drive business performance, pathways for moving from static to dynamic ecosystems, rethinking the roles of firms and individuals in institutional innovation, and the relevance of "edges" such as the maker movement, the sharing economy, and Burning Man.

Craig Giffi (principal, Deloitte Consulting LLP) is the cross-functional national industry leader for Deloitte's automotive practice in the United States. He also leads Deloitte's multiyear Manufacturing Competitiveness research initiative and is a board member of the Manufacturing Institute. Giffi is co-author of the book *Competing in World-Class Manufacturing: America's 21st-Century Challenge*. He has been a guest lecturer at the GE Whitney Symposium, the Council on Competitiveness, the Global Federation of Councils on Competitiveness, the World Economic Forum's annual meeting in Davos, Switzerland, the Woodrow Wilson International Center for Scholars, and the Aspen Institute.

Mengmeng Chen (former research fellow, Deloitte Center for the Edge) is passionate about making, manufacturing, and empowering individual creativity. While at Deloitte Consulting LLP, she worked in the Human Capital practice helping clients facing dramatic industry transformations. At the Center for the Edge, her research and analysis included the maker movement, manufacturing, and macro trends that shape today's business landscape.

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Executive summary

MANUFACTURING is no longer simply about making physical products. Changes in consumer demand, the nature of products, the economics of production, and the economics of the supply chain have led to a fundamental shift in the way companies do business. Customers demand personalization and customization as the line between consumer and creator continues to blur. Added sensors and connectivity turn "dumb" products into "smart" ones, while products increasingly become platforms—and even move into the realm of services.

As technology continues to advance exponentially, barriers to entry, commercialization, and learning are eroding. New market entrants with access to new tools can operate at much smaller scale, enabling them to create offerings once the sole province of major incumbents. While large-scale production will always dominate some segments of the value chain, innovative manufacturing models—distributed small-scale local manufacturing, loosely coupled manufacturing ecosystems, and agile manufacturing—are arising to take advantage of these new opportunities.

Meanwhile, the boundary separating product makers from product sellers is increasingly permeable. Manufacturers are feeling the pressure—and gaining the ability—to increase both speed to market and customer engagement. And numerous factors are leading manufacturers to build to order rather than building to stock. In this environment, intermediaries that create value by holding inventory are becoming less and less necessary.

Together, these shifts have made it more difficult to create value in traditional ways. At the same time, as products become less objects of value in their own right and more the means for accessing information and experiences, creating and capturing value has moved from delivering physical objects to enabling that access.

These trends can affect different manufacturing sectors at different rates. To determine the speed and intensity of the coming shifts in a particular sector, companies should consider factors including the extent of regulation, product size and complexity, and the sector's level of digitization.

As these trends play out in a growing number of manufacturing sectors, large incumbents should focus more tightly on roles likely to lead to concentration and consolidation, while avoiding those prone to fragmentation. The good news is that three roles driven by significant economies of scale and scope—infrastructure providers, aggregation platforms, and agent businesses—offer incumbents a solid foundation for growth and profitability. Due to competitive pressures, large manufacturers may experience increasing pressure to focus on just one role, shedding aspects of the business that might distract from the company becoming world class in its chosen role. The likely result is a significant restructuring of existing product manufacturers.

The growth potential of adopting a scale-and-scope role can be further enhanced by pursuing leveraged growth strategies. Rather than focusing solely on "make vs. buy" options, large players will have an opportunity to connect with, and mobilize, a growing array of new entrants, many of which will target fragmenting portions of the manufacturing value chain in order to deliver more value to their customers. Two emerging business models, "product to platform" and "ownership to access," seem particularly promising in terms of driving leveraged growth strategies.

Finally, given the emergence of more complex ecosystems of fragmented and concentrated players across a growing array of manufacturing value chains, businesses that understand emerging "influence points" will have a significant strategic advantage. As the manufacturing landscape evolves and competitive pressure mounts, driven by the needs of ever more demanding customers, position will matter more than ever.

In all the decisions about where and how to play in this new environment, there is no master playbook—and no single path to success. But by understanding these shifts, roles, and influence points, both incumbents and new entrants can give themselves the tools to successfully navigate the new landscape of manufacturing.

Introduction

ON the cavernous show floor of the 2015 International Consumer Electronics Show in Las Vegas, you come across yet another new company and product. FirstBuild is presenting the Chillhub, an open-source USB-connected refrigerator. You may wonder about the uses of such a product. Not to worry: Members of the FirstBuild community have already come up with more than 50 possibilities—including an LED disinfecting light, a hyperchiller, and an egg carton that doubles as an egg cooker. Several of these ideas are now being prototyped to test their market viability.[1]

FirstBuild is a new entity, but it's not another Silicon Valley startup. Instead, it's a microfactory set up in Louisville, Kentucky, by General Electric's appliance division. Its mission: to design, build, and market-test new innovations. For FirstBuild, GE has partnered with Local Motors, a small company that crowdsources and manufactures automobiles, to apply its platform to home appliances. The goal is to tap the extensive reach, creativity, and skills of online and off=line communities to ideate, prototype, build, and sell more products, far more quickly than would be possible within GE's established systems and structures. In short, GE is taking a page from the startup playbook in a bid to stay relevant and competitive.

FirstBuild is both an admission of the limitations of current scale-based R&D systems and a bold move to benefit from the structural speed and agility of low-capital-intensive leveraged models. In many ways, its creation reflects a growing recognition of the shifts underway in the manufacturing industry—shifts that are making manufacturing's traditional business model, that of simply making things and selling them at a profit, increasingly obsolete.

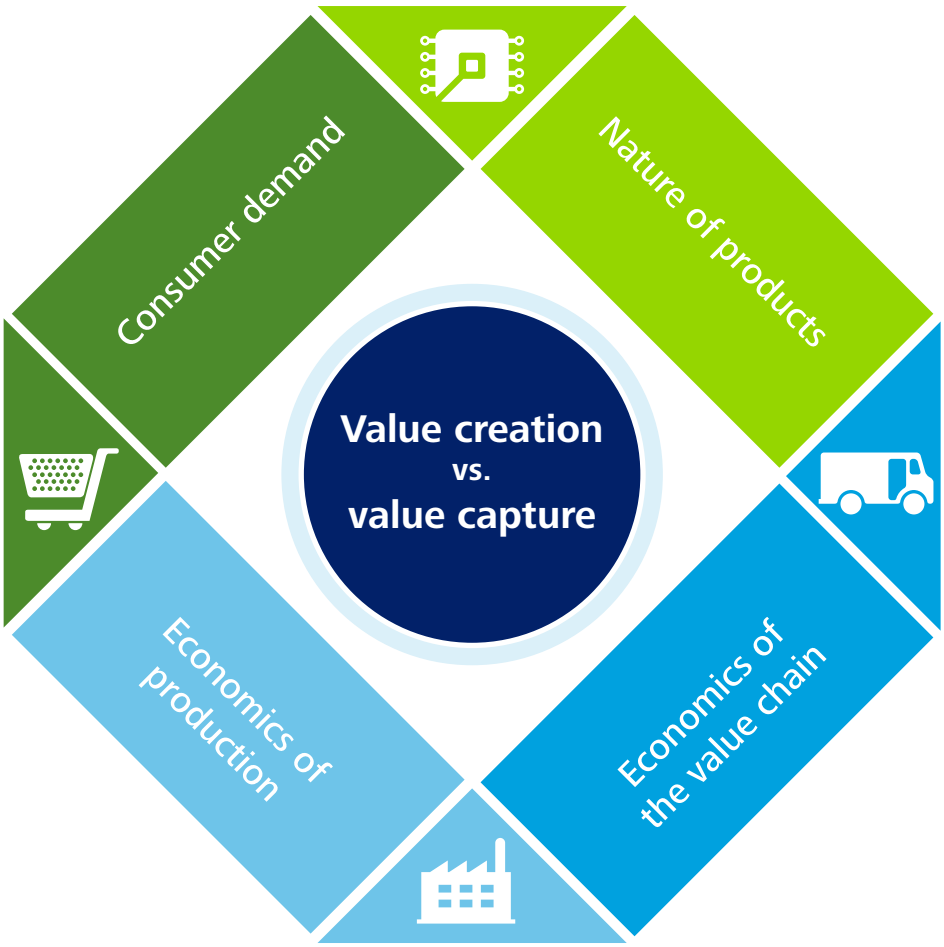
The first of these shifts is the end, for all intents and purposes, of a manufacturer's ability to create and capture value solely by making "better" products. For decades, manufacturers have been pursuing "more for less," focusing on delivering increasing product quality and functionality to consumers at lower and lower prices. But while this model served manufacturers well when improvements were relatively few and far between, accelerating technological change—and the consequent shortening of the product life cycle—has reduced the window of opportunity for capturing value from any given improvement to a sliver of what it once was. And in an era of global competition, most of the already small gains in margin from product improvement are often competed away, with the consumer as the beneficiary.

With delivering more for less no longer a sustainable strategy, forward-thinking manufacturers are looking for alternative ways to create and capture value. They are being forced to rethink old notions of where value comes from, who creates it, and who profits from it, broadening their idea of value as a point-of-sale phenomenon to include a wide array of activities and business models. It is no longer

just about selling the product, but about gaining a share of the value it generates in its use. Consider the value that Netflix generates through the use of televisions as a conduit for streaming entertainment—or the value that businesses such as Zipcar and Uber create through the use of cars for on-demand mobility. Manufacturers are waking up to possibilities such as these and, in the process, starting to transform the way they do business.

Against this backdrop, a second, parallel shift is taking place. It arises from a confluence of factors moving scale upstream and fragmentation downstream in the manufacturing supply chain. Advances in technology and changes in marketplace expectations are making it possible for relatively small manufacturers to gain traction and thrive in an industry where scale was once a virtual imperative. Thanks to technologies that are reducing once-prohibitive barriers to entry, and encouraged by fragmenting consumer demand, modestly sized new entrants now pose a legitimate threat to large, established incumbents. Indeed, in the race to find new ways to create and capture value, their smaller size and agility may give many market entrants an advantage over larger, older organizations, if only because incumbents may find it difficult to change entrenched business models and practices to accommodate new marketplace realities. Moreover, the new entrants are not necessarily even manufacturing companies in the traditional sense. The growing popularity of "smart" products, for instance, has

Figure 1. Four shifts in manufacturing



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prompted some technology companies to make forays into the manufacturing space, either by developing software to run the products, or by producing the products themselves.

Incumbents may, of course, choose to meet new entrants on their own ground, finding ways to create and capture value that rely more on capitalizing on a product's value-creating attributes than on selling the product itself. But there's another option. Some incumbents, viewing the proliferation of fragmented smaller players as a market in itself, may opt to support niche manufacturers by providing them with products and services for which scale still provides an advantage—platforms for knowledge sharing, components upon which niche manufacturers can build, and the like. Due to competitive pressures, large incumbents will likely consolidate further, providing the foundation for a large number of fragmented smaller players dedicated to addressing the increasingly diverse needs of the consumer. The result is an ecosystem that includes both niche players and large scale-and-scope operators.

Facing these two macro shifts, manufacturers—both incumbents and new entrants, from both traditional and nontraditional backgrounds—must understand the forces driving the industry's evolution in order to choose their path forward. How can large incumbents take advantage of emerging tools, techniques, and platforms? What lessons can new entrants and incumbents alike learn from organizations from other industries that have staked a claim in the manufacturing space? And how can organizations find profitable and sustainable roles in the future manufacturing landscape?

With these questions in mind, we take a deeper dive into four areas whose changing dynamics underlie both of the shifts we have described, exploring the trends and factors that influence each one:

- **Consumer demand:** Consumers' rising power and unmet needs around personalization, customization, and co-creation are causing niche markets to proliferate.
- **Products:** Technological advances enabling modularity and connectivity are transforming products from inert objects into "smart" devices, while advancements in materials science are enabling the creation of far more intricate, capable, and advanced objects, smart or otherwise. At the same time, the nature of the product is changing, with many products transcending their roles as material possessions that people own to become services to which they buy access.
- **Economics of production:** Technologies such as additive manufacturing are making it possible to cost-effectively manufacture products more quickly, in smaller and smaller batches.
- **Economics of the value chain:** Digital technologies are narrowing the distance between manufacturer and consumer, allowing manufacturers to bypass traditional intermediaries.

Each of these shifts—in customer demand, the nature of products, the economics of production, and the economics of the value chain—contributes to an increasingly complex economic environment that makes value creation more challenging while making value capture even more crucial (see figure 1). After exploring the evolving landscape, this report lays out steps both entrants and incumbents can begin to take to effectively navigate this landscape of the future. When navigating the path to enhanced value creation and value capture, large incumbents, especially, should determine the urgency of change in a given market, focus on the most promising business types, pursue leveraged growth opportunities, and identify (and, where possible, occupy) emerging influence points. The path to success is specific to each business, and businesses should envision their organizations in new ways if they want to make the most of the available opportunities.

The changing nature of consumer demand

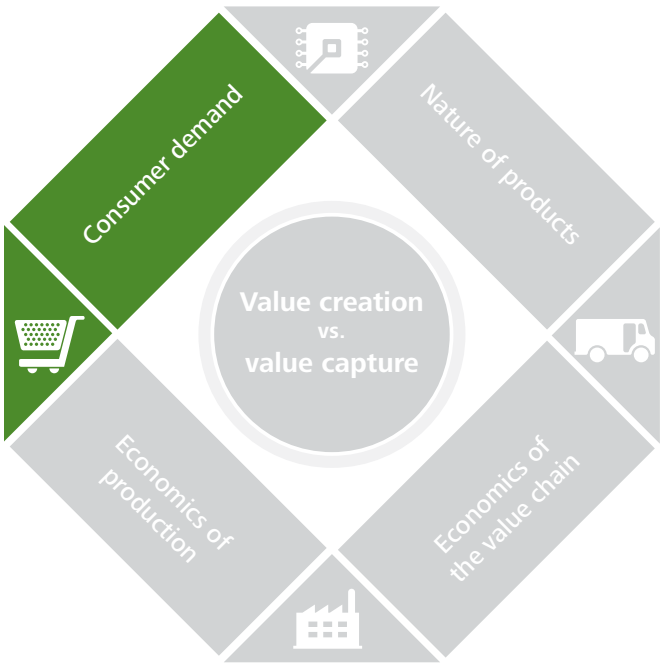
SPEND a few minutes browsing through Pinterest (the popular "scrapbooking" site for collecting and sharing visual ideas and images) or Etsy (the massive online sales platform for individual craftspeople) and you'll get a visceral sense of shifting retail demand. More and more, buyers are seeking—and finding—products that are personalized and customized to fit their individual needs. In this landscape, Pinterest reveals desire, and Etsy embodies the ability to fulfill it.

Chris Anderson described this phenomenon in his book *The Long Tail*: an increased shift away from mainstream products and markets at the head of the demand curve, replaced by a gravitation toward multiple, ever-expanding niches that constitute the curve's "long tail."[2] The ubiquity of platform and application (app) models, represented most famously by the iTunes and Android platforms, exemplifies both the increase of niche demand and the ability to service it to capture value.[3] At the same time, consumers are embracing personalization, customization, and cocreation, generating an abundance of niche markets.

Personalization and customization

At its simplest, personalization—adding to or changing a product to fit the individual—can be as simple as monogramming a towel; customization involves creating products attractive to specific niche markets. But the current rise in both personalization and customization is more than cosmetic. It's the difference between adding your name to a mass-produced object and generating a product made for your unique body, between buying a pair of drugstore reading glasses and receiving chemotherapy optimized for your particular tumor.

Personalization (to the individual) and customization (to a niche) have always taken place. Historically, however, they've been the province of the wealthy, with offerings such as custom tailoring and high-performance automobiles. No longer. Digital technologies,



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especially the Internet, have made personalization and customization available to a wide range of consumers, making it more cost-effective to satisfy demand. As a result, tailored products for niche markets are becoming increasingly available and accessible, raising consumers' expectations of being able to get exactly what they want as opposed to settling for mass-produced items. This, in turn, is fragmenting the consumer marketplace into numerous niche markets, each of which represents an opportunity for manufacturers capable of delivering the desired goods and creating and capturing value through economies of scope rather than economies of scale.

One such niche market is the tiny home movement, in which residents seek to live well in smaller spaces as a way of reducing costs or increasing geographic mobility. These consumers seek out products tailored to their limited spaces, favoring the deliberately compact, multifunctional, and aesthetically bold. Websites such as apartmenttherapy.com[4] and tinyhouseblog.com[5] tout ideas and profile living spaces appealing to the community. A growing number of craftspeople and small manufacturers reach these buyers through sites like Etsy; mass-market furniture sellers such as IKEA also focus on serving them.

Another niche market being transformed by customization and personalization is the disability community—which encompasses not only those with physical disabilities, including blindness and mobility issues, but also those with perceptual and learning differences such as dyslexia.[6] A growing number of startups are developing technologies and manufacturing new products that can be customized or personalized for this audience at a radically lower cost than even two or three years ago. Lechal is a Hyderabad-based hardware startup whose haptic devices offer tactile feedback for the visually impaired; one product incorporates electronics into shoe soles, aiding navigation with directional vibrations.[7] Many such companies are using technologies designed for the mainstream to serve their niche. For example, the recent explosion of consumer-grade additive manufacturing technologies and printers has led Enable to build a platform matching owners of 3D printers to children requiring artificial limbs. The company has also developed open-sourced designs for printable custom-fit artificial limbs. At the commercial level, related technology reaches a wider audience with products such as Invisalign's custom dental braces and Normal Earphones' custom 3D-printed earphones.

Consumers as creators

Beyond their rising interest in personalization and customization, consumers are also increasingly apt to engage in the creation, or at least the conceptualization, of the products they buy. At base, this phenomenon represents a shift in identity from passive recipient to active participant—a blurring of the line between producer and consumer.

One manifestation of this trend is the growing popularity of the maker movement—a resurgence of DIY craft and hands-on production among everyone from Lego-obsessed kids to enthusiastic knitters, electronics geeks to emerging product designers. Those involved in "making" see themselves in a different light in relation to the products they use. Some actually take on the mantle of maker, taking pride in creating rather than consuming. Others, while not producing objects themselves, become collaborators, engaging with maker culture to support and shape the products they buy, and deriving identity from that engagement. As more and more makers begin selling their creations and customizations, it's given rise to a thriving ecosystem of platforms and niche providers, including learning tools, digital repositories, service bureaus, tool shops, kit manufacturers, crowd platforms, and online and off-line retail outlets. Most of these niche providers are small startups and microbusinesses, though several have grown to a point where they're challenging incumbents—and redefining how demand is both expressed and satisfied.

The maker movement is aptly named. Its biggest and best-known event, MakerFaire, was launched by Maker Media in 2005. By 2014, there were more than 100 MakerFaires around the world, with flagship events in the San Francisco Bay Area and New York attracting more than 200,000 visitors.[8] The so-called "gym for makers," TechShop, recently opened its eighth location in Arlington, VA. Across the United States, more than 200 such "hacker spaces" give users access to the tools and training they need to create in wood, metal, plastic, fabric, and electronics while communing with likeminded creators.[9]

Even those outside maker culture are becoming more likely to seek involvement in shaping what they purchase. This involvement can take the form of voting for favorite designs on an ideation platform, crowdfunding a hardware startup, or engaging an Etsy seller to create a custom item. More-involved individuals might customize or hack a build-it-yourself product kit, design and build pieces from scratch, or sell their creations to others within or outside the movement.

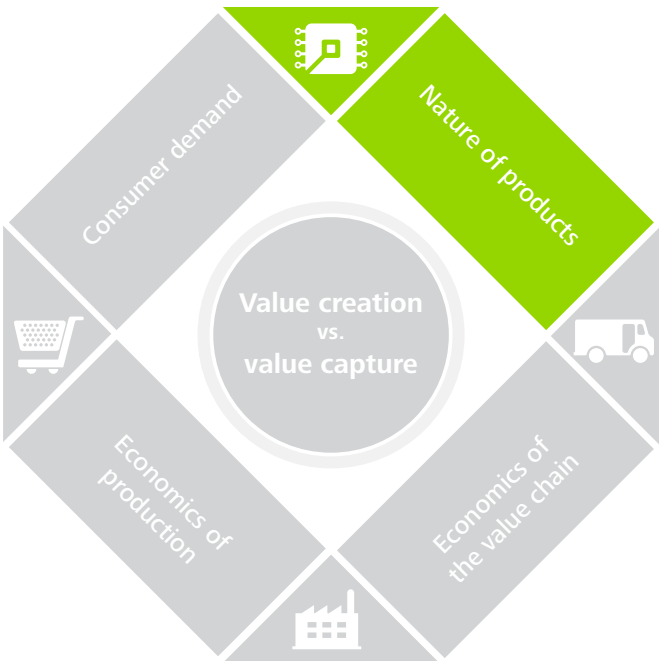
This incipient change in identity from consumer to creator is also driving a change in how brands are perceived. Many consumers want to get past the marketing to create a more authentic relationship with the products they consume. This impulse feeds into the growing "buy local" movement as well as into the growth of retailers such as Etsy (which brought in more than $1.35 billion in 2013), connecting buyers to craftspeople and their stories.[10] At all levels of engagement, participants endeavor to put a personal stamp on the products they consume—and put pressure on manufacturers large and small to deliver products that enable a higher level of engagement and authenticity.

As consumer demands shift toward personalization, customization, and creation, we will see an increasing proliferation of niche markets where, rather than "settling" for mass-market products, consumers will be able to find or even create products suited to their individual needs. In this environment, manufacturers fully leveraged to produce large volumes of limited numbers of products will likely be at a disadvantage, forcing them to rethink their place in the manufacturing landscape and the value they bring the consumer. The good news is that amid the fragmentation, new roles and new sources of value can emerge for large players.

The changing nature of products

In parallel with, and in response to, shifts in consumer demand, the nature of products is changing. "Dumb" products are getting "smarter"—more connected, intelligent, and responsive. At the same time, how consumers view and use products is changing, redefining both the factors that determine product value and how companies can capture it.

As clothing becomes "wearables," cars "connected cars," and lighting "smart lighting," will the majority of the benefits accrue to the product manufacturer, the software platform owner, the creator of the "killer app" that makes the product come alive, or the company that generates insights from the resulting big data? The questions raised go far beyond the technical challenges of manufacturing. As products create and transmit more data, how much value will be located in the objects themselves, and how much in the data they generate, or the insights gleaned from it? And what of the option to rethink products as physical platforms, each the center of an ecosystem in which third-party partners build modular add-ons? Each of these questions envisions a change in the nature of products—and a much larger shift in how value is created and captured.



Source: Center for the Edge

From dumb to smart

This year's Consumer Electronics Show (CES) in Las Vegas featured nearly 100 smart watches and health and fitness trackers.[11] At the simplest level, these devices logged activity; more complex versions tracked breathing patterns and measured body composition.[12] In deference to consumers' demands for good design, nearly all paid at least some attention to aesthetics. Quite a few led with their looks: Smart-device startup Misfit partnered with Swarovski to produce the Swarovski Shine Collection, nine crystal-studded jewelry pieces, each concealing an activity tracker.[13]

Such items are good examples of the quantified self movement, in which participants use technology to track and analyze the

data of their daily lives. As yet, most are still stand-alone tools. The next generation of these devices, however, is likely to be integrated into our clothing and accessories so seamlessly that they become "wearables."

The emergence of technologically enabled products such as activity trackers is only one facet of a looming transition in physical goods. In the near future, many, if not most, "dumb" products will become "smart"—falling under the umbrella of the Internet of Things (IoT). The pervasive expansion of sensors, connectivity, and electronics will extend the digital infrastructure to encompass previously analog tasks, processes, and machine operations. Gartner analysts predict that by 2020, the IoT will include nearly 26 billion devices, adding $1.9 trillion in global economic value.[14] In a recent survey, nearly 75 percent of executives indicated that their companies were exploring or adopting some form of IoT solution, with most seeing integrating IoT into the main business as necessary to remain competitive.[15]

The evolution of "smart" products presents manufacturers with challenges on multiple levels. Some of these products incorporate complex software or interact with users' smart devices, while others use cutting-edge materials—such as electroactive polymers and thermal bimetals—that continually adapt to users' changing needs. Further, not all products will be smart in the same way and, as smart products become more complex, it will be increasingly difficult for any single manufacturer to develop an entire hardware/software stack in house.

To capture value in a world where products are as much about software as about physical objects, manufacturers should consider their business models in the light of four factors that play into generating value from smart products: integrated software, software platforms, the applications (apps) that run on those platforms, and data aggregation and analysis. While integrated software handles all the performance functions needed by the hardware housing it, software platforms act as translators, managing the hardware based on new instructions delivered through easily updatable apps. This platform-plus-app model allows for a greater range of customization and personalization, and makes it easier to update products in response to shifting needs and contexts.

From product to platform

The drive for customization and personalization—coupled with the success of such platform-centric business models in software—is pushing some manufacturers to rethink products as physical platforms, with each platform the center of an ecosystem in which third-party partners build modular add-ons. This change goes beyond simply adding software to physical objects, though that is an important component of platform creation. The design of physical products is changing to allow for extensive personalization and customization, and to encourage offerings from third-party partners that increase the value of the base product.

We most often think of "platforms" in terms of software, with the most recent example being the massive success of the iOS and Android app platforms. These platforms use a leveraged growth model that relies on simple mathematics: The greater the reach and value of the extensions created, the greater the number of base-module sales.

However, platforms can also exist outside the digital world. A platform is any environment with set standards and governance models that facilitate third-party participation and interactions. Successful platforms increase the speed and lower the cost of innovation, as they reduce entry costs and risks through common interfaces and plug-in architectures. Participants can join in and collaborate, extending the platform's functionality. The more participants a platform has, the richer its feedback loops and the greater the system's learning and performance improvements.

Aftermarket add-ons—one example of a physical platform—have a long history. Thriving aftermarkets exist to customize and personalize automobiles for both utility and

aesthetics, for example. Most aftermarket products are manufactured and installed by third parties that have no affiliation with the original equipment manufacturers.[16] What is new is the upsurge of products *designed* from the start as bases for third-party extensions from partners and others. The aftermarket has become a premarket.

The view of products as platforms—as starting points for customization and personalization—has been embraced by the maker movement. In the world of furniture, for example, IKEA product lines have been further extended by consumers who "hack" off-the-shelf furniture, posting photos and instructions on Ikeahackers.net.[17] Similarly, at Mykea (thisismykea.com), artists can submit designs to "reskin" standard Ikea furniture.[18] In other product-as-platform plays, chip manufacturers Intel and AMD have had to compete with cheaper, smaller electronics platforms such as Arduino and Raspberry Pi. These platforms' successes are directly and intentionally tied to that of the extensions that consumers build on them.

Forward-thinking product manufacturers are approaching such movements, not as fringe activities, or even as threats to the brand, but as marketing opportunities—a chance to embrace a passionate, highly invested community, offering opportunities for engagement and loyalty in products designed and manufactured for hackability. They are extending the concept of the product as platform into an explicit business strategy: Introduce a product platform, then invite multiple third parties to create modular add-ons that extend the value to the customer. MIT's annual Vehicle Design Summit 10^5 competition, launched in 2013, invites 10 teams to develop automobiles standardized around five subsystems—auxiliary power unit (APU)/fuel, body, dashboard, suspension, and chassis—creating 100,000 permutations.[19] And in the for-profit world, Google's Project Ara will soon launch a modular smartphone, inviting third-party manufacturers to build niche-targeted swappable modules that fit into nine compartments in the Ara shell. A user might extend battery life with an extra battery one day, then switch out the camera for a night-vision module the next. Planned modules include chargers and connectors, screens, cameras, speakers, storage, and medical devices such as blood glucose monitors and electrocardiographs.[20] If we can endlessly customize our apps, why not the physical components of our phones?

From product to service

Where does the product end and the service begin? In one sense, this is an old question; business strategists have long advised companies to focus on the problem solved rather than on the product that solves it. Today, however, the expanding digital infrastructure—low-cost computing and digital storage, ubiquitous connectivity, and a multiplying number of connected devices—has created many more opportunities to fundamentally rethink the product as a service. This trend is most evident where the "product" is virtual, with Adobe, Autodesk, and Microsoft offering software suites via monthly subscription. At the same time, in the enterprise software market, onsite IT hardware and software is being eclipsed by cloud-based software-as-a-service (SaaS) offerings.

Opportunities to reconceptualize physical products as services are growing as well. For instance, digital infrastructure has spurred the "sharing economy"—a broad term used to describe businesses that commoditize sharing of underutilized goods and services. By moving the focus from ownership to access (collaborative consumption), this model shifts the economics of usage from product to service, giving rise to billion-dollar companies including Uber (crowdsourced transportation) and Airbnb (crowdsourced housing). Lesser-known startups have arisen to share tools, kitchen appliances, and other rarely used or underutilized products. The value created by sharing these goods is not, for the most part, being captured by product manufacturers.

INTEL EDISON: MAKING A PLATFORM PLAY FOR IOT

It's common knowledge that Intel missed the mark on mobile. For decades, the company led sales of PC processors; then, with the rise of mobile phones, ARM Holdings took the lead position in chip design and licensing by specializing in low-cost, low-power processor technology, while Qualcomm and Samsung dominated manufacturing. As long-time Intel executive Andy Bryant put it, "We're paying a price for that right now."[21] Despite Intel's many attempts to catch up, including paying subsidies to push its presence in tablets, its mobile business continues to struggle. Most recently, the division posted a billion-dollar operating loss in Q3 2014.[22]

Determined to catch the next wave, the company has invested significantly in making chips for the Internet of Things. (IDC forecasts the existence of more than 30 billion smart devices by 2020, comprising a $3 trillion market.[23]) The result is impressive: In Q3 2014, Intel's IoT chips brought in $530 million in revenue, up 14 percent year over year.[24] Then, at the 2014 Consumer Electronics Show, the company announced Edison—a low-cost, product-ready development platform designed for use in wearables, robotics, and IoT. The chip quickly gained popularity among makers for its versatility and high performance. In 2015, Intel followed up with the release of Curie, a button-sized module designed for easy integration into wearable technologies.

Unlike with the PC wave, when Intel locked in a few big partners, this time the chipmaker is allying with a wide range of smaller players. To inspire individuals and small teams to get started with Edison, and to make connections in the maker community, it has established an ecosystem designed to lower barriers to entry, putting out resources from hacker kits to user guidebooks and establishing a strong presence at events. Through the Make It Wearable Challenge, Intel is helping startups transition from idea to product; in the most recent competition, teams from all over the world came up with ideas and prototypes incorporating the Edison chip, including flyable and wearable cameras, low-cost robotic hands, and sensors for use in skiing.

For Intel, the move into the IoT market is smart business. For makers and manufacturing entrants, it's the base for an outpouring of innovative products.

There is a largely untapped opportunity for manufacturers to reconfigure their own business models, reenvisioning the nature of their products in a way that helps them take advantage of the product-as-a-service concept.

General Electric is a notable example of a company that has successfully navigated the shift from ownership to access. GE Aviation has recently taken steps to pursue a product-as-a-service business strategy for one of its major offerings. Along with Rolls-Royce and Pratt & Whitney, the GE division manufactures aircraft engines for a market of buyers led by Boeing and Airbus. These engines, which cost $20–30 million each, have long, complex sales cycles and relatively low margins.[25] Not surprisingly, more money is made servicing this equipment over its 30-year lifespan than on the initial sale. With this in mind, GE has introduced a "Power by the Hour" program that shifts from sales and service to a utility model. The idea—and the term, coined by Bristol

Siddeley in the 1960s—has since been used by other engine manufacturers, including Rolls-Royce and Pratt & Whitney. In GE's offering, after an initial setup cost, the customer pays for time used rather than equipment or service—moving from a large fixed cost to a variable cost aligned with usage. In such a scenario, the advantages to both company and customer are many. Sensors on the new engines generate real-time usage, diagnostic, and failure data. Together with a specialist team that will fly around the globe to address issues, this setup has reduced unscheduled downtime significantly.[26] More accurate data also helps the company improve both products and scheduling, reducing overall costs for both parties.

Of course, this model isn't unique to the jet engine market. In the consumer market, for instance, instead of selling manufactured solar panels, providers such as Solar City offer customers fixed utility pricing while financing the initial cost of products and installation. The story with such providers is one of both large and small competitors coming into multiple markets with a service-driven model, capturing value that manufacturers once claimed as their own. The manufacturers that respond with a new lens on products and services are those that will continue to thrive.

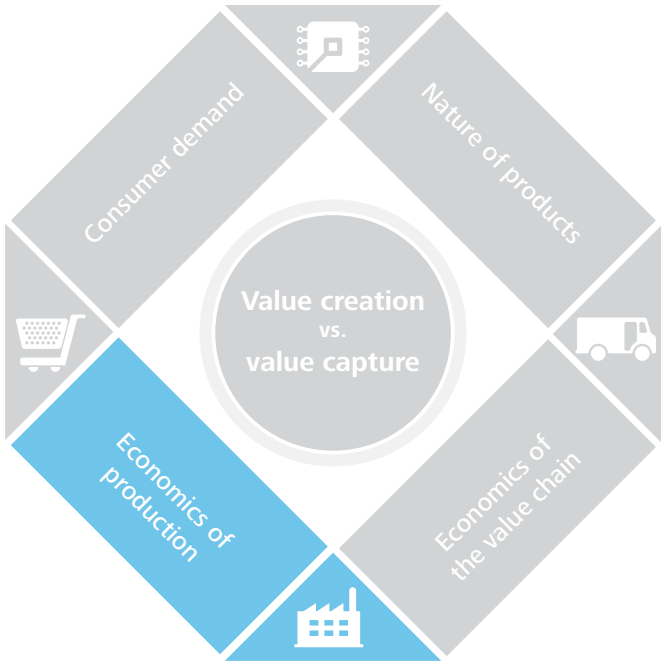
As products become "smart," connected, co-created, and even transformed into services, the whole notion of creating value solely by making and selling more items becomes obsolete. With the change in the nature of products comes a shift in value creation. In the coming landscape, value will come from connectivity, data, collaboration, feedback loops, and learning—all of which can lay the groundwork for new and more powerful business models.

The changing economics of production

MANUFACTURING, until recently, was a daunting space with relatively few players. Barriers to entry were high and initial capital investments hefty; products had to navigate multiple intermediaries before reaching the consumer. Today, however, huge shifts in technology and public policy have eroded barriers that once impeded the flow of information, resources, and products. In a world where computing costs are plummeting, connectivity is becoming ubiquitous, and information flows freely, previously cost-prohibitive tasks and business models are becoming more available to more players. Barriers to entry, commercialization, and learning are eroding, as is the value proposition for traditional intermediaries in the supply chain. Meanwhile, rapid advances and convergences in technology, including additive manufacturing, robotics, and materials science, further expand what can be manufactured and how. All of these developments are combining with changing demand patterns to increase market fragmentation, supporting a proliferation of product makers further down the value chain with more direct consumer contact. Upstream, larger manufacturers will likely consolidate, taking advantage of scale to provide components and platforms used by smaller players.

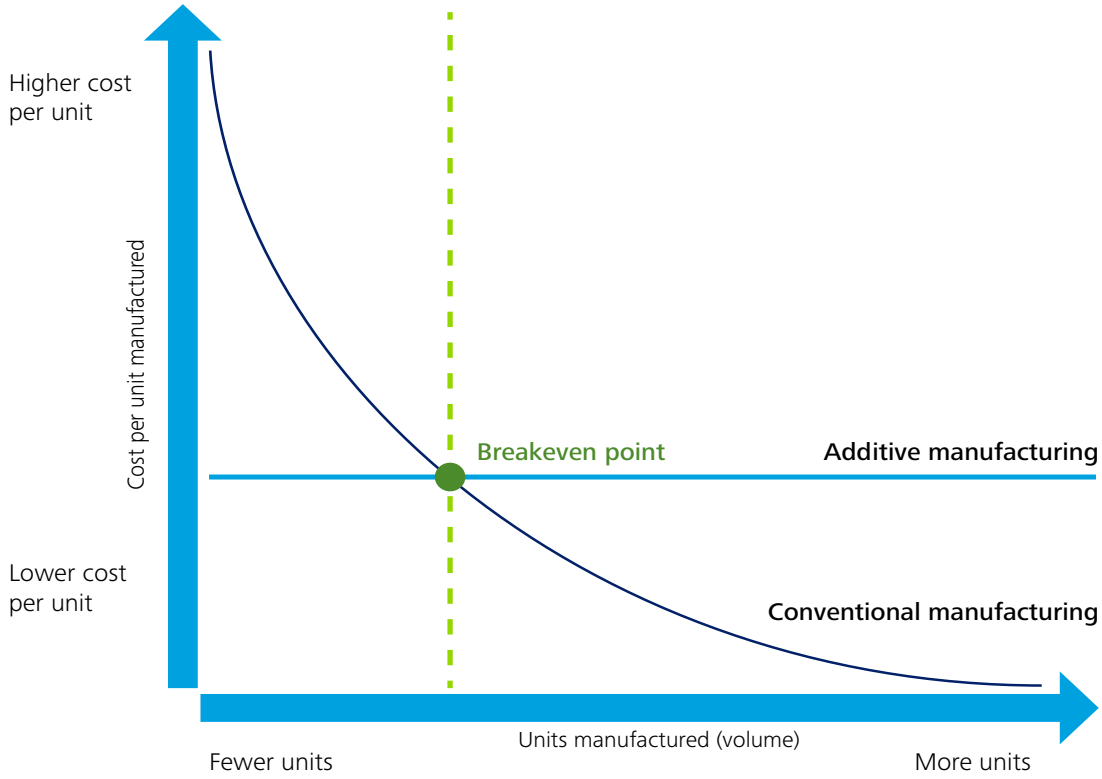
Exponential technologies

One of the most well-known ideas about digital technology is Moore's law, which describes the doubling of computer processing speed every 18 to 24 months for the past 50 years.[27] Modern computers continue to become exponentially smaller, faster, and cheaper. And as more and more technologies become digitally empowered, this pattern of growth has expanded beyond microprocessors. Emerging fields with potential for exponential growth include additive manufacturing, robotics, and materials science. The convergence of these



Source: Center for the Edge

Figure 2. Breakeven analysis comparing conventional and additive manufacturing processes



Source: Mark Cotteleer and Jim Joyce, *3D opportunity: Additive manufacturing paths to performance, innovation, and growth*, Deloitte University Press, http://dupress.com/articles/dr14-3d-opportunity/, accessed March 17, 2015.

Graphic: Deloitte University Press | DUPress.com

and other technologies has the potential to generate huge improvements in capability, utility, and accessibility.

Additive manufacturing

Additive manufacturing (AM), better known as 3D printing, encompasses manufacturing technologies that create objects by addition rather than subtraction (through milling, for example). While 3D printing technologies were developed more than 30 years ago, this decade has seen a rapid advancement in tools, techniques, and applications in both commercial and consumer arenas.

Today, while additive manufacturing is used mostly in prototyping,[28] it is expanding to other stages in the manufacturing process. Tooling—the production of molds, patterns, jigs, and fixtures—is traditionally one of the most time-consuming and costly portions of the process, far outweighing unit costs for each additional part, and leading manufacturers to spread out the up-front cost across large production runs. In contrast, the initial capital outlay for AM is typically much lower, not only because AM obviates the need for tooling, but also because the cost of AM equipment has been decreasing rapidly.

The price of additive manufacturing is dropping, making AM increasingly competitive with conventional manufacturing due to differences in fixed vs. variable costs. Even though the variable cost for AM is currently higher than that for conventional manufacturing, reduced up-front investment often makes the total cost of AM less for small production runs (see figure 2).

All of this can make AM a game-changing option for small-batch production. In addition, complexity is free with additive

manufacturing—in fact, the material cost of printing a complex design is less than that of printing a solid block, since it requires less time and material.[29] When the burden of production is transferred from the physical world to the digital world, engineers can design intricate, previously unproducable shapes. And manufacturers can produce stronger, more lightweight parts that require less assembly time, reducing the overall cost of production or increasing the value of the final product.[30]

While AM technology is still developing in terms of speed, material, and precision, many industries are already using it to create high-value parts at low volume. In coming years, we can expect the range and scale of AM deployments to extend to lower-value, high-volume items.

Robotics

Industrial robots have historically been used mostly for tasks requiring exceptional strength and precision—for example, moving heavy items, welding, and semiconductor fabrication. They required heavy up-front investment and programming, and were usually bolted to the ground and caged as a safety measure for humans working in the vicinity. Use of industrial robots was therefore limited to large-scale manufacturing.

Until recently, low labor costs plus the high price of industrial robots posed little incentive for low-wage countries to invest in automation, particularly for tasks that require relatively little training and lines of production that change frequently. Now, however, rising global labor costs and a new generation of cheaper, more capable, more flexible robots are changing the equation.

The minimum wage in the Shenzhen area of southern China has risen by 64 percent in the past four years. Some analysts estimate that, by 2019, per-hour labor costs in China will be 177 percent of those in Vietnam and 218 percent of those in India.[31] Given such projections, it's unsurprising that industrial robot sales in China grew by nearly 60 percent in 2013.[32] In 2014, China became the largest buyer of industrial robots, buying more than 36,000—more than either the United States or Japan. While Japan still has the largest total number of active robots, China is well on pace to become the automation capital of the world.[33]

The rapidly falling cost of more capable robots is a complementary factor. Unlike industrial robots of the past, "Baxter," the $22,000 general-purpose robot developed by Rodney Brooks at Rethink Robotics, can work safely alongside humans. It replaces programming with simple path guidance, allowing it to be retrained for another task simply by moving its arms to mirror the new path. Brooks' creation signals yet another shift in workforce composition, freeing unskilled labor from repetitive tasks once too expensive to automate while further enabling the use and expansion of "cobots"—robots that work directly and collaboratively with human beings.[34] OtherLab is developing "soft robots" that use pneumatic instead of mechanical power, reducing energy requirements and increasing safety while matching the dexterity and accuracy of existing mid-grade industrial robots.

Though robots will not replace human labor in manufacturing in the immediate future, they are poised to take on an increasing share of the manufacturing floor. This is likely to reduce the number of low-wage, low-skill human manufacturing jobs while generating a relatively small number of specialized higher-wage jobs in programming and maintenance.

Materials science

Since the 1960s, the term "space-age" has been used to describe new materials that enable previously impossible engineering tasks. The first generation of these materials—memory foam, carbon fiber, nanomaterials, optical coatings—has become ubiquitous. As new materials are created, older ones, once inaccessible to all but the most advanced, price-insensitive manufacturers, have begun to trickle down to the mainstream.

Take carbon fiber, the poster child of space-age materials. While the energy costs associated with its manufacture still prevent use in many low-end applications, recent technological improvements have allowed manufacturers to produce higher volumes of carbon fiber products at lower prices. As a result, it has found utility in a slew of premium products such as bicycles, camera tripods, and even structural automotive components such as drive shafts and A-pillars.[35] Lexus, for example, has developed a carbon fiber loom that, rather than forming two-dimensional sheets into three-dimensional shapes, can weave seamless three-dimensional objects.[36] As manufacturing improvements lower costs and other barriers to access, we can expect to see such materials used in more mainstream applications. For example, Oak Ridge Labs has realized a 35 percent reduction in carbon fiber costs, and BMW plans to bring the cost of carbon fiber production down by 90 percent.[37] In fact, lower costs and streamlined manufacturing processes are slated to double global carbon fiber production by 2020.[38]

The effects of such gains extend far beyond making it cheaper to manufacture high-tech items. Battery technology, for example, has seen dramatic performance improvements over the past decade as a result of materials science innovations. It has been predicted that advancements in chemistry and materials science will result in an 8 to 9 percent annual increase in the energy density of batteries.[39] Other nascent technologies have the potential to vault past the capabilities of commonly used materials—even the first generations of space-age materials—by orders of magnitude. Carbon nanotubes, for example, have one of the highest tensile strengths of any material while serving as one of the best conductors of both heat and electricity.[40] They can carry four times more energy than copper while retaining the physical characteristics of a piece of thread.[41] Researchers have envisioned applications including composite materials stronger than carbon fiber, advanced water filters, syringes that can inject genetic information into cells, solar panels, and artificial muscle fibers.[42]

Meanwhile, materials are being developed from new sources. MycoBond offers a flame-resistant Styrofoam alternative grown from Mycelium fungus.[43] Hobbyists can now make thermoplastic at home using simple online instructions and the starch from a grocery store potato.[44] And researchers are making surgical-grade plastic from silk.[45] Like carbon nanotubes, these materials have potential in higher-performance settings. Nanocrystalline cellulose, a renewable material abundant in wood fiber, has potential applications ranging from plastic and concrete reinforcement to conductive paper, batteries, electronics displays, and computer memory.[46]

Other high-performance materials adapt to their environments. Dynamic materials such as electroactive polymers (polymers that change shape when exposed to an electric charge) and thermal bimetals (metals that change shape as temperatures change) have demonstrated potential for use in adaptable architecture. When used as the outer skin of a building, these materials can expand when it is hot to cool structures, and close when it is cold to preserve heat. Dynamic materials have also demonstrated value in more personal applications. The Phorm iPhone® case by Tactus uses electronically controlled fluids to create physical key guides on top of an existing iPad® or iPhone keyboard, giving the user a tactile keyboard or a flat, uninterrupted screen as the situation demands.[47] As these materials develop, we can expect to see more physical objects reacting dynamically to suit our needs across contexts.

While not everyone will have immediate access to newly developed materials, the barriers to entry for advanced, customized manufacturing will be reduced as advancements in materials science progress—opening up space for new players in cutting-edge manufacturing.

CONVERGING TECHNOLOGIES' IMPACT ON MANUFACTURING

No technological development exists in a vacuum. As more and more technologies reach a stage of aggressive growth, they are more likely to intersect, generating growth greater than the sum of their parts. When discussing the impact of converging exponential technologies on the manufacturing landscape, bear in mind that each technology will compound the capabilities of others, enabling previously unforeseeable innovations.

For instance, materials science is fueling the expansion of additive manufacturing by increasing the range of printing materials. 3D printing has historically used plastics such as ABS and PLA, but newer machines can print in a wide range of materials, greatly increasing the technology's reach. Modified PLA filaments impregnated with maple wood, bronze, iron, or ceramic are now available at the consumer level, allowing designers to create objects with characteristics of the chosen material.[48] For more technical applications, MarkForged is developing a way to print PLA objects infused with carbon fiber, fiberglass, or Kevlar, making load-bearing 3D-printed objects, some with higher strength-to-weight ratios than aluminum, viable. Christian von Koenigsegg of the Swedish supercar manufacturer Koenigsegg has discussed the utility of this technology in low-volume, high-performance applications such as supercar manufacturing. Other companies have made significant headway in the 3D printing of complex, highly engineered parts—for instance, GE's titanium jet engine turbine blades. Chinese construction firms are printing five-story cement apartment buildings in Suzhou Industrial Park. Electronics manufacturers can use 3D printers to seamlessly embed electronics in printed housings or, by combining conductive and structural materials in the same device, print intricate electronic circuitry within an object during production.[49] 3D printers have also found use in medicine, printing custom hip replacements that facilitate bone growth—and even recreating human organs using a mix of alginate and human stem cells.

Autodesk CEO Carl Bass has spoken extensively on convergence in design software and computing. In this area, Moore's law has enabled price reductions to a point at which computing power's incremental cost is functionally zero. This has allowed more people to use advanced modeling capabilities to produce detailed models of any physical object, without having to physically make it. This capability is supplemented by advancements in energy, materials science, nanotechnology, sensors, and robotics, which in turn allow for development and deployment of even more advanced technologies. The result is an interrelated technological economy in which progress in one industry directly affects progress in another. As more technologies approach an exponential turning point, we can expect to see even more such complex and dynamic relationships, further accelerating the progress of technology as a whole.

Eroding barriers to learning, entry, and commercialization

One of the strongest effects of the exponentially developing digital infrastructure is its ability to break down barriers, opening the manufacturing world to newcomers. As knowledge and information are digitized, it's easier than ever to learn a new skill or connect with experts in any field, to enter a market that once required high investment capital, and to commercialize an opportunity from a product to a business. These benefits, first evident in the digital world, are now reaching physical manufacturing, where they are likely to spur both growth and change.

Lower barriers to learning

What does a Millennial (or at this point, anyone) do to learn something new? Google it. Or, in broader terms, search online. How-to videos on pretty much any topic can be found on YouTube. Websites such as Instructables, Hackster, and Makerzine feature thousands of step-by-step projects in text and video. Discussion forums in communities of interest deepen learning with conversations—often mixing amateurs and experts—that address specific problems. Such online discourse is then extended to "real life" via tools, like Meetup, that make it easy to gather a group around a topic or "learning/hacking" session. Communities form around institutions such

as TechShops and Fab Labs or events such as MakerFaire, MakerCon, SOLID, and the Open Hardware Summit, all of which include hands-on learning sessions. In short, the transfer of tacit knowledge—knowledge gained by doing—has become easier with the ready availability of both online and real-world events, each of which enhances the other.

The resulting influx of makers and startups drawn from these communities, and the ease of acquiring design and production skills, fuels the number of market entrants. While entrants are unequipped to challenge incumbents directly, they are both the sign and the result of rapid innovation; the areas where they innovate will be loci of change and growth in the nature of manufacturing. Note that barriers to learning have come down not just around design and production, but throughout the manufacturing-to-sales process. From desktop tooling to freelance engineering talent, crowdfunding to business incubators, a whole ecosystem has arisen to help budding manufacturers learn the ways of designing, manufacturing, and selling a product.

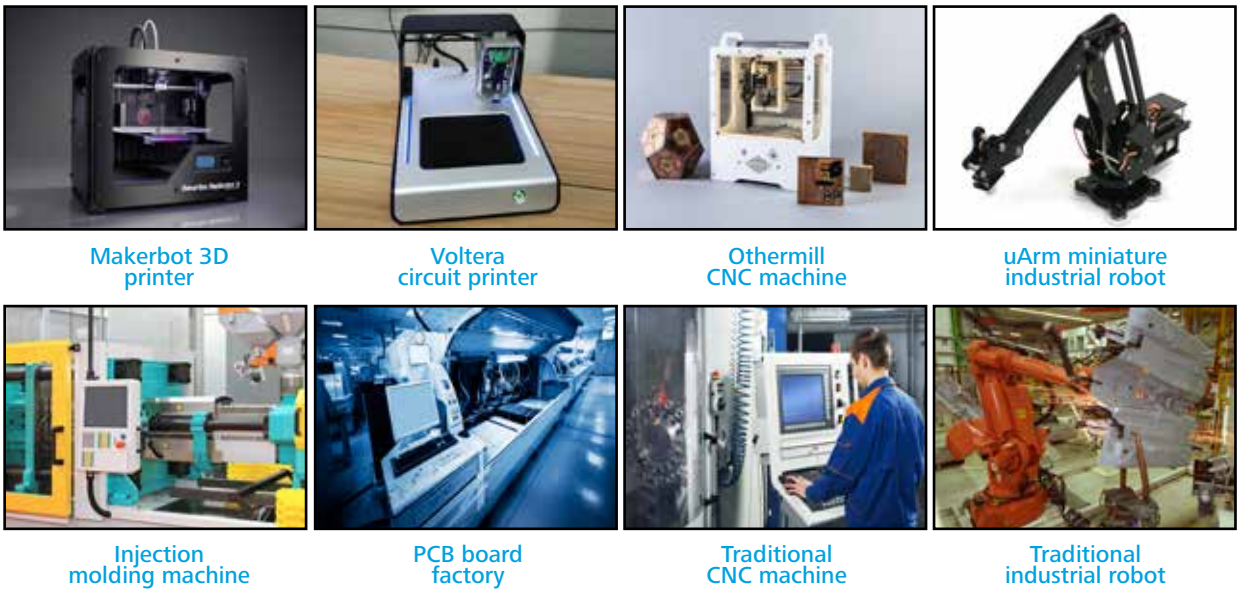
Lower barriers to entry

The digital infrastructure-based benefits that supported the rise of software startups at the turn of the century have now extended to hardware startups. In addition to pay-per-use models that allow for access to high-end computing power through offerings such as Amazon's AWS service, an array of boutique agencies, freelance creative and technical consultants, and service marketplaces give prospective hardware entrepreneurs access to programming, design, and engineering talent on an as-needed basis. At the low end, sites such as Fiver.com offer ad hoc services for as little as $5 an hour. And support for small providers of first services, and now products, is growing rapidly. Coworking spaces such as Hub and Citizenspace provide shared office space and ancillary support, reducing the initial investment and effort needed to launch a business.

Both tooling technology and tool access have also been democratized. TechShop offers members access to complex design and tooling equipment for roughly the cost of a monthly

Figure 3. Sample of tools that lower barriers to production

Manufacturing tools have become smaller and less expensive, democratizing access to sophisticated design and tooling capabilities for use in prototyping



Source: Center for the Edge

Graphic: Deloitte University Press | DUPress.com

Figure 4. Factors affecting barriers to learning, entry, and commercialization

Source: Center for the Edge

Graphic: Deloitte University Press | DUPress.com

gym membership. A slew of desktop manufacturing modules, from 3D printers and CNC milling machines to printed circuit board (PCB) printers and pick-and-place machines, has hastened the speed of prototyping and small-scale manufacturing (see figure 3). As former *Wired* editor and 3D Robotics founder Chris Anderson put it, "Three guys with a laptop used to describe a Web startup. Now it can describe a hardware startup as well."[50]

Lower barriers to commercialization

Barriers to initial funding and commercialization are also falling, making it easier than ever to enter a market, commercialize a creation, and build a business. Crowdfunding of hardware projects has become both popular and lucrative, reducing reliance on financing through bank loans and venture capital. Initial capital often covers tooling costs, requiring only enough revenue to cover production. Crowdfunding sites such as Kickstarter and

Indiegogo have also allowed startups to identify early adopters, develop a loyal customer base, and establish demand prior to producing a single item. Venture funders have taken notice, increasing their funding of hardware startups, while a slew of hardware incubators and accelerators help startups move from idea to prototype to business.

Traditional large-scale manufacturers are playing a role here as well. In early 2015, FirstBuild, the GE subsidiary, launched its first crowdfunding campaign on Indiegogo for the Paragon Induction Cooktop, a Bluetooth-enabled tabletop cooker—and the test case for the company's new manufacturing model. And in 2014, Foxconn, the world's largest contract manufacturer, sectioned off a portion of one of its factories to house Innoconn, a startup incubator and microfactory targeting initial product runs of 1,000 to 10,000—a dramatic shift for a firm once accessible only to blue-chip brands with multimillion-unit orders.[51] While Innoconn represents only a tiny fraction of Foxconn's total production volume, it demonstrates the willingness of even the largest firms to learn small-batch

PCH: FROM PRODUCT CONCEPT TO PRODUCT DELIVERY—A PLATFORM FOR HARDWARE ENTREPRENEURS AND STARTUPS

Launched in 1996 as a one-man sourcing operation for computer parts, PCH is now a billion-dollar firm employing more than 2,800 people across the globe.[52] The company spans the supply chain, designing custom manufacturing solutions for *Fortune* 500 companies as well as startups. From design manufacturing and engineering to packaging and fulfillment to logistics and distribution, PCH offers a variety of services to the hardware industry.

In addition to manufacturing, fulfillment, and postponing facilities in Shenzhen, PCH works with a network of factories. In the past few years, PCH has added, through acquisition or organic growth, a hardware accelerator (Highway1), a division to help startups scale (PCH Access), an engineering and design division (PCH Lime Labs), an e-commerce platform (Fab.com), and distribution and fulfillment capacity (TNS).[53] Reflecting its mission to help startups and incumbents make products and get to market, the company recently rebranded operations under the slogan "PCH: We make" and the tagline "If it can be imagined, it can be made."

A recent "Demo Day" showcased the range of hardware startups PCH supports, including a company pitching smartphone-controlled haptic wearables, a connected water pump for home usage monitoring, a heads-up display for car navigation and connectivity, and smart jewelry.

While a growing number of accelerators help entrepreneurs and startups navigate the value chain, PCH is emerging as one of the first to do so from concept to delivery, lowering barriers to entry and increasing speed to market. PCH founder Liam Casey notes, "Time is the number-one currency in this business."[54] His network delivers a boost that can make the difference between success and failure or, at a minimum, provide a crucial understanding of how to scale. For the current Goliaths of consumer electronics, it is the slingshot that could empower a thousand Davids.

manufacturing and support the growing small-company segment of the manufacturing landscape. By appropriating formerly small-scale funding and production practices like crowdfunding and small-batch manufacturing, big manufacturers can reap the benefits of both their size and the new methods' agility.

Emerging manufacturing models

Responding to the growing opportunities presented by niche markets, and drawing on technologies that make it possible to cost-effectively manufacture small batches or even single instances of many items, manufacturing is shifting from a predominantly scale-driven operation to a sector characterized by multiple production models. Large-scale production will always dominate some segments of the value chain, but three other manufacturing models are arising to take advantage of new opportunities: distributed smaller-scale local manufacturing, loosely coupled manufacturing ecosystems (like that in Shenzhen, China), and an increased focus on agile manufacturing methods at larger operations.

While each of these models reduces costs, they also reimagine and restructure how products are made, with a deep long-term effect on value creation. The emergence of business models centered on niche markets and smaller-scale production makes it easier for new entrants to establish themselves, attract customers—and potentially eat into the mass markets traditionally served by large-scale manufacturers, on whose platforms they may very well rely.

Distributed local manufacturing

In the twentieth century, an intense focus on cost reduction and efficiency led manufacturers to decamp to countries with low labor costs and to maximize efficiencies gained through mass production. In the United States and Europe, what little domestic manufacturing remained served premium or craft markets. But a recent rise in local manufacturing is bucking that trend, relying on technology and community to keep costs down.

Over the last decade, Brooklyn, NY fashion designer Bob Bland experienced the reduction of US apparel manufacturing capacity firsthand—followed by the dwindling of the value chain from raw materials to machinery, the tacit knowledge of the community that supported it, and the opportunity to connect customers' wants and needs with what gets produced. In 2014, to help reverse this trend, Bland founded Manufacture New York, a sprawling 160,000-square-foot fashion design and production center in Sunset Park, Brooklyn. Her aim: to enable more small manufacturers to subsist locally and be more responsive to local needs.

AtFAB, a design firm cofounded by architects Anne Filson and Gary Rohrbacher, aims to design simple, durable furniture that can be produced locally using digital CNC fabrication tools. Filson and Rohrbacher design and test furniture in their studio, then post the digital files on OpenDesk, "a global platform for open making," for others to download, customize, and cut using CNC machines.[55] OpenDesk has connected a community of designers, local machine shops, and users to drive momentum for the distributed manufacturing movement; its goal is to reduce the environmental impact of shipping, increase local employment, and provide consumers with customizable designer furniture for a fraction of the retail price.[56] To support the makers who buy and use designs like AtFAB's, community organizations such as 100KGarages.com are building local capacity for digital fabrication while educating members, building community—and extending the value of digital platforms such as OpenDesk.

The digitization of manufacturing, along with the exponential growth of subtractive and additive digital fabrication technologies and robotics, has made manufacturing more repeatable and portable. Individual designers and small businesses now have the ability to produce high-quality goods locally at low cost. Increased digitization is likely to further lower

LOCAL MOTORS: PROOF OF CONCEPT FOR DISTRIBUTED LOCAL MICRO MANUFACTURING

In September 2014, at the International Manufacturing Technology Show (IMTS), a car was 3D printed live for the first time. The Local Motors Strati, based on a contest-winning design by Michele Anoe, took 44 hours to print, another day to CNC mill the body to its final shape, and two more days to assemble additional components.[57]

The Strati combines new (community-driven, micro manufacturing) business models with new (3D printing) technology to reimagine the nature and process of auto manufacturing. In summer 2015, Local Motors will put the results into practice, opening a combination micro-manufacturing facility and retail outlet dedicated to designing, printing, and selling the Strati. In doing so, it will embody a workable example of distributed local micro manufacturing—and stand as a harbinger of change for manufacturing of even large, complex, and heavily regulated products.

In just eight years, Local Motors has upended conventional thinking about what can be manufactured and how. Founded in 2007 by Jay Rogers, the company has created a set of tightly integrated physical and virtual platforms where a community of designers, makers, and engineers come together to design, build, and sell vehicles.[58] With its first product, the Rally Fighter, a street-legal off-road automobile, Local Motors redesigned the manufacturing process to work without a steel press, instead building a metal frame and attaching composite body components. This led to a much less capital-intensive process that enabled small-scale distributed manufacturing. The Rally Fighter is sold as a kit car to overcome US regulatory hurdles.

the cost of customization, giving more advantage to distributed small-scale local manufacturing that captures consumer needs.

Loosely coupled manufacturing ecosystems

Shenzhen, a city in southern China, was established in 1979; today, it is the anchor city of China's Special Economic Zone, the global epicenter of consumer goods manufacturing.[59] While the zone's largest manufacturers are known worldwide, some of the more interesting players in this ecosystem are part of a network of smaller factories, called Shanzhai, that evolved around the giants, originally manufacturing gray-market or pirated products but now entering legitimate commerce. These smaller manufacturers' size, plus their network of interconnections, enable them to perfect small-lot manufacturing while iterating at incredible speed. Their operators—many former factory workers who have branched out into ownership—have mastered the ability to build high-quality products at low volumes and low cost, at extreme speed, using an ecosystem of loosely coupled small to medium-sized factories and individual experts. The result is a system that can take on the larger Shenzhen factories—and one that is extremely well suited to emerging modes of supply. The beneficiaries are any designers or brands, large or small, established or new, that want to jump in, iterate quickly and cheaply, and scale as needed to meet demand.

Over the last two decades, Shenzhen, which the *Huffington Post* has dubbed "Silicon Valley for hardware," has drawn expert engineering and manufacturing talent.[60] Those who left the zone's large manufacturers to set up small factories started working together, building a loose but powerful network of knowledge, skills, and capabilities—and creating a near-ideal environment for constant learning. New demands led to new tools and techniques, with network members working together to push the boundaries of capability and cost. One highly visible result is the plethora of inexpensive, high-quality mobile phones dominating the Chinese market. As newer trends such as IoT, wearables, and robotics gain momentum, the Shanzhai are likely to respond with equal alacrity and range.

The geographic density of Shenzhen, and its ability to encompass the entire value chain from raw material suppliers and industrial equipment manufacturers to designers, product manufacturers, and assemblers, is unlikely to be replicated exactly. However, similar hubs have appeared elsewhere in China, with footwear manufacturing in the Fujian region and motorcycle manufacturing around Chongqing. Other, more traditional global manufacturing hubs have the potential to spawn similar loosely coupled networks, mirroring the Shanzhai's system and success.

Agile manufacturing

For larger manufacturers, renewed interest in agile manufacturing is helping them remain competitive while staying responsive to increasingly fickle and unpredictable market signals. The key to this increased agility: a digital infrastructure that provides access to near-real-time point of sale (POS) data, rather than lagging monthly or quarterly sales reports.

The more accurate such forecasts are, the more sense it can make to choose highly efficient large production runs. However, when introducing a new product with less certainty of market acceptance, or making upgrades or changes to a product design, manufacturers may instead choose to focus on producing "minimal viable batch quantities," matching agile manufacturing practices with agility in the supply chain. Overseas production and freight shipping will force minimum manufacturing quantities to compensate for long lead times from production to customer. For smaller items, the cost of air freight and short fulfillment cycles may trump the cost of holding inventory, cost of capital, and obsolescence.

SHANZHAI: EXTENDING THE VALUE OF SOLOWHEEL

Inventor Shane Chen emigrated from China to the United States in the 1980s, attracted by the American culture of entrepreneurship. In 2012, he introduced the Solowheel, a self-balancing electric unicycle with a starting price of $1,599—a price that made it difficult to move beyond the Western early-adopter audience.[61] While the creativity of the Solowheel is notable, an equally interesting—and more far-reaching—story can be found in the response of the loosely coupled manufacturing ecosystem of Shenzhen, China.

Within a few months of the Solowheel's US introduction, multiple knockoffs, and—more interestingly—dozens of variants of the Solowheel appeared on Chinese e-commerce sites. Most were produced by factories in Shenzhen. There were Solowheel-like products with two wheels, ones with seats, others with holders for tablets (to aid in navigation). Prices ranged from $200 to $800.[62]

On a recent trip to China, the authors of this report visited one Shenzhen factory, Shenzhen Teamgee Electronic Co., or STEC, that manufactures the motorized unicycles. The factory owner had come across the Solowheel on a trip to the United States, and was intrigued by its potential as a last-mile transportation device for the Chinese market. He reached out to "brother factories" in his network, and together they reverse-engineered and reproduced the product. One factory did the battery system, another the motor; STEC handled the plastic molding and electronics. Within a month, the factory network had a product ready for market. Six months later, it was selling the third-generation product.

Beyond the impressive speed of iteration was the even more striking ability to improve performance while continuing to cut costs with each cycle. The most recent version, the TG T3, retails at $229. A fourth generation is in the design phase now—the embodiment of a system honed at every point to take advantage of the emerging value chain.[63]

Taking all these factors into account, contract manufacturer PCH International demonstrates the benefits of agile manufacturing. In-house tracking technology allows the company to track each order from click to delivery in a single system, "managing to an order of one." PCH can also customize individual orders at the final assembly level. For Neil Young's high-end music device, the Pono Player, the buyer can choose a product color, select the signature of a favorite artist to be engraved on the casing, and have his or her choice of music preloaded. Beyond using technology to support agility, the company

has reengineered its manufacturing lines to be modular—and so easy to update that the minimum viable batch quantity equals the number of products produced on one manufacturing line during a single shift.

As technology advances exponentially and barriers to learning, entry, and commercialization continue to decrease, product development and commercialization will further fragment. New entities may find it increasingly easier to enter the landscape and to create products addressing specific consumer niches. These businesses will proliferate, though each will be limited in size by "diseconomies of scale"—the larger they get, the less relevant they will become. Meanwhile, as consumer demand fragments, so will addressable markets, making the notion of "mass market" more and more irrelevant. In this manufacturing environment—with the downstream fragmenting as scale moves upstream—businesses seeking growth will need to rethink the ways they participate in the manufacturing landscape.

SEEED STUDIOS: EMBRACING AGILE MANUFACTURING

At MakerCon 2014, Seeed Studios CEO Eric Pan stepped onstage wearing a hand exoskeleton for remote robotic control. It was an early prototype of Dexta Robotics' Dexmo, a 3D-printed exoskeleton combined with inexpensive sensors that could control a robotic device by mirroring the wearer's hand movements. While commercial robotic control systems cost tens of thousands of dollars, the Dexmo prototype was hacked together for under $100.[64]

The Dexmo control arm was designed to illustrate the concept of "design *from* manufacturing"—using readily available components manufactured by the millions to reduce product cost. In this case, the ingenuity lay in replacing expensive bendable sensors with a combination of cheap, easily acquired or manufactured parts.

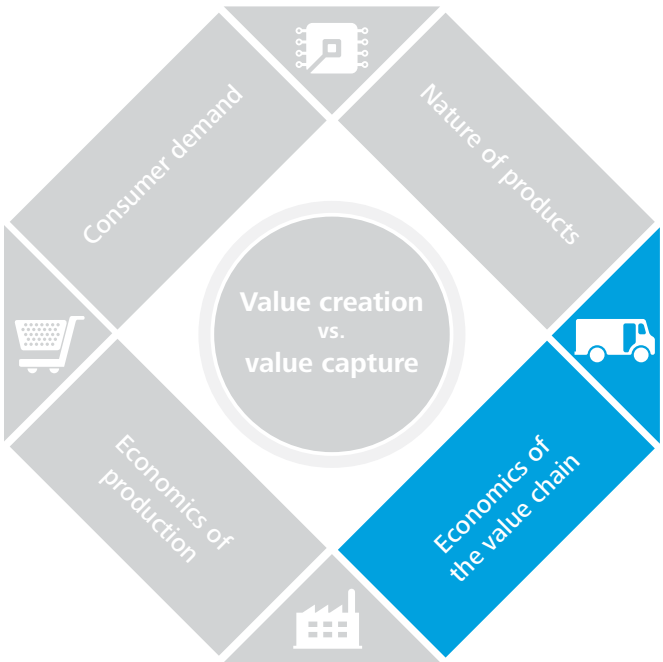
Seeed is among a growing number of companies that have extended the web of manufacturers and sourcing companies from Shenzhen to the broader world. The Shenzhen-based firm was founded as a bridge between Western makers and China's agile manufacturing ecosystem. In addition to in-house manufacturing facilities, it has developed relationships with a range of specialized manufacturers and component providers. The company emphasizes "design *from* manufacturing and design *for* manufacturing," aiming to design with manufacturing specs in mind; its Open Parts Library (OPL) catalogues compatible components for the most widely used parts in printed circuit board (PCB) designs. This allows even novice makers to reduce costs and error rates by specifying mass-produced, highly compatible components.

The OPL and connecting to the Shanzhai ecosystem are two of many ways that Seeed Studios has embraced agile manufacturing. The result: increased connection, lower barriers to prototyping, and an overall increase in the pace of product innovation.

The changing economics of the value chain

THE lines between manufacturers (which make things) and retailers (which sell things) are blurring. This softening of roles has significance not just for the companies undergoing a transformation, but also for any intermediaries holding inventory along the way.

While a few companies are vertically integrated across the value chain, most traditional manufacturers are a few steps removed from their products' end consumers. In a world where information travels ever more freely, and where cycle times are collapsing, traditional players can struggle to communicate with consumers and to receive—and act on—timely, meaningful feedback. Consumers feel this disconnect as well, and many are opting to connect more directly with the makers of the products they consume.



Source: Center for the Edge

These disconnects can have multiple implications for how value is created and captured. As the distance between manufacturer and consumer narrows, intermediaries whose sole value is to hold inventory are likely to be squeezed out. The most likely survivors will be those that create more value for consumers, perhaps by providing useful information, helping people make choices, or allowing buyers to experience products in new ways. For the same reasons, successful manufacturers will be those that can engage directly with consumers, narrow the gap between prototype and product, and move their business models from build-to-stock to build-to-order.

While no single small company can have a major impact on large incumbents, a slew of agile startups taking market share from the incumbents can create significant change. Entrants are using three approaches to gaining a toehold in the new manufacturing landscape, each at a distinct point in the value chain: engaging the consumer directly, increasing speed from idea to market, and favoring build-to-order over build-to-stock.

WARBY PARKER: RETHINKING THE VALUE CHAIN

Eyewear startup Warby Parker was founded in 2010 by four entrepreneurs who saw a problem with the industry—the high cost of glasses. Explains founder and co-CEO Neil Blumenthal, "We were tired of radically overpaying for eyeglasses. It didn't make sense to us that a pair should cost as much or more as an iPhone; glasses were invented more than 800 years ago and don't contain rare minerals or state-of-the-art technology."[65]

The company hit a nerve. Since its founding, it's been growing rapidly despite entering an industry almost entirely closed to outsiders; eyewear is dominated by a single player, Luxottica Group, with a stake in almost every part of the supply chain, including manufacturing (Oakley, Ray-Ban), distribution, retail (Sunglass Hut), and even insurance (Eyemed). All told, Luxottica controls 80 percent of all major eyewear brands. As often happens in industries dominated by a single player, market prices have stayed high, with an average 20x markup on each pair of glasses sold.[66]

Warby Parker's response was to develop its own vertically integrated model, cutting out most of the licensing fees and middlemen. It sourced frames directly from manufacturers (including those providing competitors' $700 frames) and kept all product design in house, a practice uncommon in the industry.[67] This model allows the company to sell a pair of frames with prescription lenses directly to the consumer, without insurance subsidies, for $95. At the same time, it distributes another pair of glasses to a wearer in the developing world. As of this writing, Warby Parker has sold more than a million pairs of glasses and distributed nearly a million more.[68]

In line with the incredibly personal nature of glasses—which are both a medical device and a lifestyle item—the company combines the convenience of online ordering with customers' need to experience the product in person. Customers can select up to five frames and try them out for five days for free. This program appeals to and maintains full control of the distribution network while bypassing the existing brick-and-mortar infrastructure. Recently, Warby Parker has expanded its business model to include brick-and-mortar stores; as of 2015, the company had retail stores in seven cities with showrooms in an additional six, further extending its vertical depth.[69]

Eroding value proposition for intermediaries

In a traditional value chain, the manufactured product goes through a series of wholesalers, distributors, and retailers before reaching the consumer. Inventory is held at each of these intermediary stops to buffer for variable demand. Capital is held hostage for a few months, tied up in shipping and inventory until products are sold. It's no surprise that the manufacturer's suggested retail price (MSRP) is usually four to five times the ex-factory cost of a product: A lot of money (and, traditionally, value) is stuck in intermediaries. But as the digital infrastructure continues to cut the distance between manufacturer and consumer, this model, and its conception of value, will most likely be questioned and restructured.

When search cost was high, a retail outlet providing multiple side-by-side options had value. Convenience also dictated having as many items as possible available in one location. But then online sales brought consumers

not just a near-infinite number of options, but reviews and feedback that helped buyers choose among them. Meanwhile, quick (even overnight or same-day) shipping has become cost-effective when substituted for the cost of multiple intermediaries. While choice and convenience alone may not be adequate value drivers for intermediaries, in this time of transition, as consumers are retrained in new behaviors (online purchasing and ship-to-door), retailers' traditional sources of power, geographic spread and physical shelf space, are slowly slipping.

In this environment, many hardware startups are forgoing traditional brick-and-mortar retail channels, going directly to consumers via online platforms, such as Amazon, eBay, and Etsy, that offer advantages to both buyers and sellers. While getting on the shelves of a brick-and-mortar retailer can boost sales, it can also create a cash crunch when most of a small firm's revenue is stuck in inventory or held hostage to long payment terms. As the value captured by controlling access to physical space and consumer access erodes, retailers that want to stay relevant as value chain players will have to reevaluate and reconfigure their business models. Eyeglass manufacturer Warby Parker, for example, has been growing at a rapid pace in an industry historically closed to outsiders, largely due to its ability to bypass traditional distribution and retail channels. As a result, the company is able to offer high-quality frames at lower prices, unlocking value otherwise taken up by intermediaries.

Direct consumer engagement

Traditionally, the consumer has been a few steps removed from the product manufacturer. Today's hardware startups, however, are using the digital infrastructure to connect directly with the consumer, building affinity for both product and company. As technology evolution accelerates, they focus on brand affinity rather than traditional intellectual property (IP) patent filings and protection.

While consumer engagement is not usually seen as part of the supply chain, it is testament to the power of direct engagement that it can be redefined as a very early point in that chain—which may today be more aptly called the value chain. Many of these startups are using crowdfunding platforms not only to raise initial capital, but to build a community of fans and supporters around their products—engaging demand in a way that ties it inextricably to supply. In shifting the power balance for market entrants, this stance strikes at the heart of the question of how to capture value, and which entities (new entrants or incumbents, small businesses or large) will do so.

In crowdfunding campaigns, consumer engagement does not end with the campaign; rather, businesses continue to connect and communicate with supporters throughout the manufacturing process, offering detailed updates on both successes and challenges. The Pebble E-Paper Smartwatch, an early entrant into the smartwatch market in 2012, was one of the earliest crowdfunded hardware successes. After failing to raise money from venture capital firms, founder Eric Migicovsky was looking for $100,000 to move from prototype to manufacture. After raising $10,266,845 from 68,929 backers, Pebble stopped its crowdfunding campaign early for fear of not being able to fulfill all of its orders.[70] Despite being heavily funded, the company ran into manufacturing problems, due to everything from adhesives that performed badly in Shenzhen's humid climate to universal work stoppage for Chinese New Year. Though product delivery was delayed by several months, Migicovsky kept the crowdfunding community in the loop, offering detailed reports including play-by-plays on manufacturing fumbles. Community members were extremely supportive, even suggesting potential solutions and recommending specification upgrades, several of which were incorporated into the product. In the end, a highly engaged, loyal community and customer base helped the Pebble gain market traction where other, larger firms had failed.

Faster speed to commercialization

While small manufacturers such as Pebble embrace a measured pace of development informed by community engagement, larger players are more likely to distinguish themselves through speed. And with ever more rapid shifts in consumer demand, speed to market is increasingly important. "Fast fashion" sellers such as TopShop, for example, credit their success in large part to optimizing manufacturing and the value chain to address changes in consumer tastes and demands.

With the success of such models, manufacturers have inevitably followed suit, working to compress time from idea to market. One major draw of manufacturing consumer electronics in Shenzhen is "Shenzhen sudu" (Shenzhen speed), which allows sellers to capture market value almost as fast as it can be identified.[71] For the Solowheel (described previously), this resulted in development of dozens of lower-priced substitutes only weeks after the initial product was released. Today, such rapid speed to commercialization is poised to become the rule rather than the exception.

Build to order vs. build to stock

Traditional manufacturing practices are still built around a "build to stock" model—demand is forecast, and then the product is manufactured to fit that forecast, taking into account multiple lead times along the value chain. But with the ability to engage the consumer directly online come new "build-to-order" models driven by online promotion and preorders. In many respects, crowdfunding for new products is a kind of preorder. While build-to-order manufacturers may still use forecasting to optimize manufacturing efficiency, preorders are even better at gauging consumer demand.

San Francisco clothing startup BetaBrand, for example, designs and releases a few limited-edition designs every week for preorder. This structure reduces the risk of excess inventory and gives the company constant demand data. Threadless, another clothing startup, hosts a platform on which designers can submit designs for users to vote on. Users can preorder T-shirts, hoodies, posters, or card packs printed with the winners. Threadless then produces the items, paying designers a royalty.

As consumer preferences shift toward personalization, customization, and creation, direct access to consumers will become critical. Intermediaries reduce speed to market and require capital to build up inventory; they can also make it more difficult for manufacturers to access valuable consumer insights. However, many large manufacturers today rely heavily on intermediaries, weakening their connection to the consumer. This puts them at a disadvantage when compared to smaller players with direct consumer relationships that make them more responsive to changing consumer needs. Large manufacturers should consider how they might use their scale to enable these smaller players instead of competing with them directly.

XIAOMI: SUCCEEDING WITH ADAPTIVITY AND RESPONSIVENESS

Singles' Day, held on November 11, is China's equivalent of Cyber Monday (the 1s in the date, likened to "bare sticks," represent unmarried people). In the five years since the holiday's introduction by massive e-retailer Alibaba (which logged $9.3 billion in sales on Singles' Day 2014), November 11 has become the world's biggest online shopping day. 2014's best-selling product, the Mi, is the creation of smartphone manufacturer Xiaomi, which sold 1.16 million Mi phones in 24 hours, totaling $254 million in sales. The four-year-old company is now the world's third-largest smartphone manufacturer, trailing only Apple and Samsung.[72]

Xiaomi launched in 2010, starting with software—the Android-based operating system MIUI—long before it entered the hardware market. The company prides itself on its ongoing weekly operating system updates; at the time of writing, MIUI had been updated every Friday for more than four years.[73] This extreme adaptivity and responsiveness to user feedback quickly attracted a dedicated fan base; by the time the first Xiaomi smartphone was released in August 2011, MIUI had accumulated 2.5 million users—including overseas fans who voluntarily translated the platform into 20-plus languages.[74] Though today the main draw of the company is arguably its hardware, the OS is still an important pillar in the Xiaomi ecosystem.

As the company's history shows, Xiaomi's founders never saw it as just a hardware company. In 2011, cofounder Lei Jun described the shift in market competition: "Competition used to be a marathon; you only needed to know how to run. Now the game is an Ironman triathlon. To compete, a company must offer great hardware, software, and Internet services."[75]

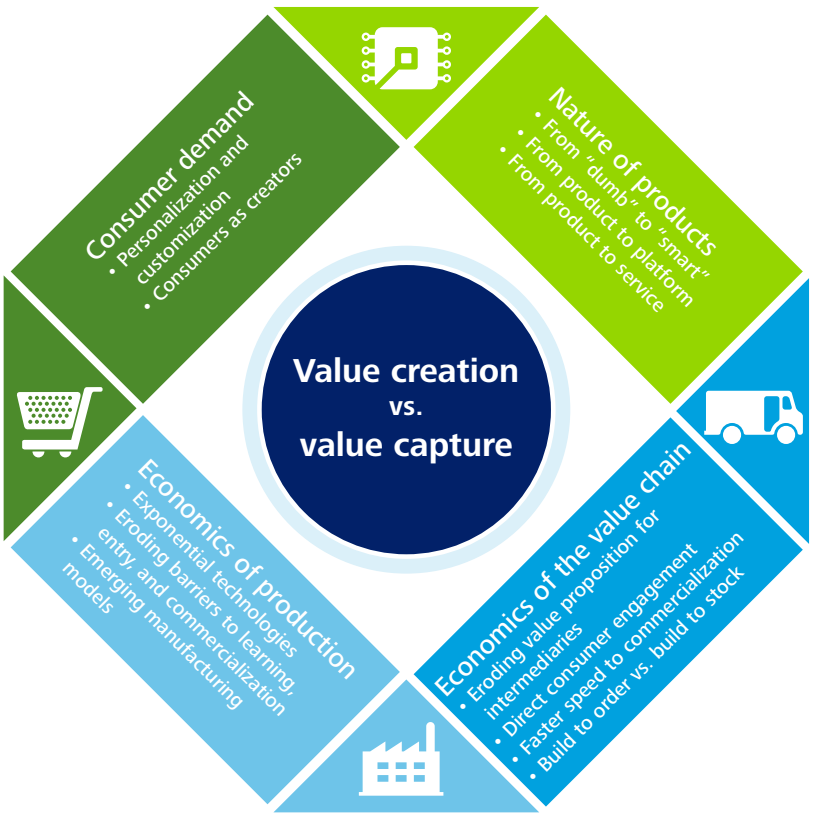
With hardware manufacturing, Xiaomi has put significant energy into both community engagement and fast iterations. Product managers spend approximately half their time in user forums, and the company can incorporate user suggestions in a matter of weeks. Today, Xiaomi ships a new batch of phones every week, and "every batch is incrementally better," says VP of international sales Hugo Barra.[76] And active consumer engagement has allowed the company to spend very little on PR and marketing, especially in its early days. Instead, it spends on online and off-line events, including an annual Mi fan festival.

Rather than pursuing traditional distribution and retail, Xiaomi generates 70 percent of its sales online, driving demand from fans, who often preorder or participate in flash sales to get their hands on new products.[77] This huge preorder demand allows the company to build to order, purchasing components only after orders are placed and eliminating risks associated with surplus raw material and warehousing. Still, given retail prices that cut very close to manufacturing costs, there is quite a bit of speculation about the exact source of Xiaomi's profitability. One sign of ongoing growth is its successful entry into additional hardware categories, including tablets, routers, and televisions—all of which have benefited from the company's quick turns and dedication to its customers.

Navigating the future manufacturing landscape

THE world of manufacturing is shifting exponentially. Not only is it becoming more difficult to create value, but those who do so are not necessarily those best positioned to capture it. Value resides not just in manufactured products, but also in the information and experiences that those projects facilitate. For example, today's televisions, despite being many times more powerful than those of just a decade ago, are priced so competitively that neither manufacturers nor retailers can maintain anything more than the smallest margin on their sales. Rather than delivering value in their own right, televisions have become a *vehicle* for the locus of value—the content that viewers watch on them. With this fundamental

Figure 5. Factors that affect creation and value capture in manufacturing



Source: Center for the Edge

Graphic: Deloitte University Press | DUPress.com

shift in value from object to experience—or more specifically, from device to the experience facilitated by that device—comes the need for manufacturers to redefine their roles, and hence their business models.

The same trends that have pushed manufacturing in the direction of delivering more value for lower cost—and that have made it about far more than producing physical products—will become more and more pronounced over the next few decades. To succeed, products will have to be smarter, more personalized, more responsive, more connected, and less expensive. Manufacturers will face increasingly complex and costly decisions about where and how to invest in order to add value.

When assessing the future manufacturing landscape, there is neither a single playbook for incumbents nor a single path for new entrants. Instead, companies should consider these recommendations when navigating the path to enhanced value creation and value capture:

- Determine the urgency of change in your specific market
- Focus on the most promising business types
- Pursue leveraged growth opportunities
- Identify and, where possible, occupy emerging influence points

Determine the urgency of change in your specific market

As consumer demands shift, the nature of products and production changes, and intermediaries disappear, we will see increasing fragmentation in the manufacturing landscape. As lowered barriers to forming a business intersect with increasing consumer demand for personalization, the manufacturing landscape will begin to fragment in ways that touch the consumer. We'll likely see a wide range of individual players, each focusing on a small, addressable market around a specific niche; both niches and players will proliferate over time. Collectively, these businesses can address a broad spectrum of consumer and market needs, with no single player having enough market share to influence the long-term direction of its domain. This situation will be sustained by the need for only modest investment to enter and maintain one's position, combined with "diseconomies of scale" that make it more difficult for larger players to compete at this level.

Fragmentation will occur mostly around specialized product and service markets, with a wide range of small players either designing and assembling niche products or serving as supporting domain experts or contractors. We see this pattern now in the growth of small hardware startups associated with the maker movement, as well as with sellers on websites such as Etsy.

However, accelerated technological change is likely to have a markedly different effect on this era of manufacturing than it has had in the past. Where before, new industry segments consolidated into a few dominant players as their industries matured, the future manufacturing landscape is poised to experience rapid, ongoing disruption leading to continuous fragmentation.

Fragmentation will occur at varying rates and to varying degrees across regions, manufacturing subsectors, and product categories. All segments of manufacturing will eventually be affected, with timing and speed of disruption varying based on the industry's exposure to shifting trends. Barriers to entry in the form of factors such as regulation, design complexity, size of product, and digitization will affect which subsectors first experience disruptive shifts. However, the speed of the shift will vary greatly even within industry segments—for example, electronic toy manufacturers will have very different experiences from makers of board games, stuffed animals, or building toys. Understanding the timing and speed of change in their industries and subsectors will help businesses assess when and where to play in these changing times.

The factors at play aren't static. The regulatory environment is constantly evolving in response to market needs. Product complexity, size, and digitization are all affected by exponentially evolving technologies. When considering these factors, it is important to evaluate not just the current placement of your product category, but also potential shifts that could accelerate fragmentation in parts of the business landscape.

The regulatory environment

Public policy and regulation play a profound role in the current and future structure of the manufacturing ecosystem. Trade agreements, labor relations, consumer safety and environmental regulations, and privacy and security restrictions all have the power to shape and shift its dynamics and economics. In a survey of 400 CEOs in all major industries, respondents listed the regulatory environment as their top concern, with more than 34 percent reporting spending an increasing amount of time with regulators and government officials.[78] Industries with complex supply chains spanning multiple geographies can struggle to change practices developed in response to regulatory requirements. In general, the greater an industry's regulation, the greater the barriers to entry and the slower the pace of fragmentation. Governments can speed the transition to a more fragmented manufacturing ecosystem by relaxing regulation and encouraging new entrants and innovation. For example, tax treatments in China's Special Economic Zones spurred many foreign and domestic companies to relocate, quickly expanding the country's manufacturing sector.

Product complexity

The more complex the product—measured by the number of components, the intricacy of component interactions, and the extent of product novelty—the more the parties designing parts of the final product must interact. In general, this factor matters most during design and prototyping. This means that, the more complex the product, the greater the value of in-house R&D or collaboration by a few tightly coupled players, and the more resources a manufacturer should have in house—and the more difficult disruption in the form of fragmentation becomes.

However, this is not always the case, as exemplified by the first Apple iPod. Faced with an incredibly tight timeline, the designer, Portal Player, tightly defined boundary conditions for each product component, then invited multiple players to compete for the best design in each category. This approach allowed for greater innovation in the final product—as specialists worked on each part of the player—but led to more work for the engineers designing and testing how all the parts came together.

Product complexity is also changing as a result of exponential technologies such as 3D printing. The advent of the 3D-printed car took the car from 20,000 parts to 40, significantly reducing product complexity—and enhancing the potential for smaller players to enter the design and final assembly market, leveraging the capability of a few large-scale component providers.[79] 3D-printed parts are also agnostic as to design complexity; complex geometries can be printed just as easily as a solid block.

Product size

Regardless of product complexity, physical product size matters. The larger the physical product, the more costly it is to prototype, manufacture, store, and ship. The equipment and space needed to tinker with a small consumer electronics device is much less than that required for a home appliance. And such requirements amplify as a product moves from tinkering to prototyping and on to production. Across the board, categories including larger products will be slower to fragment, in part because their shipping costs make up a significantly higher portion of the final delivered cost to the consumer. As Local Motors CEO Jay Rogers puts it, "For local to go big, big needs to go local."[80]

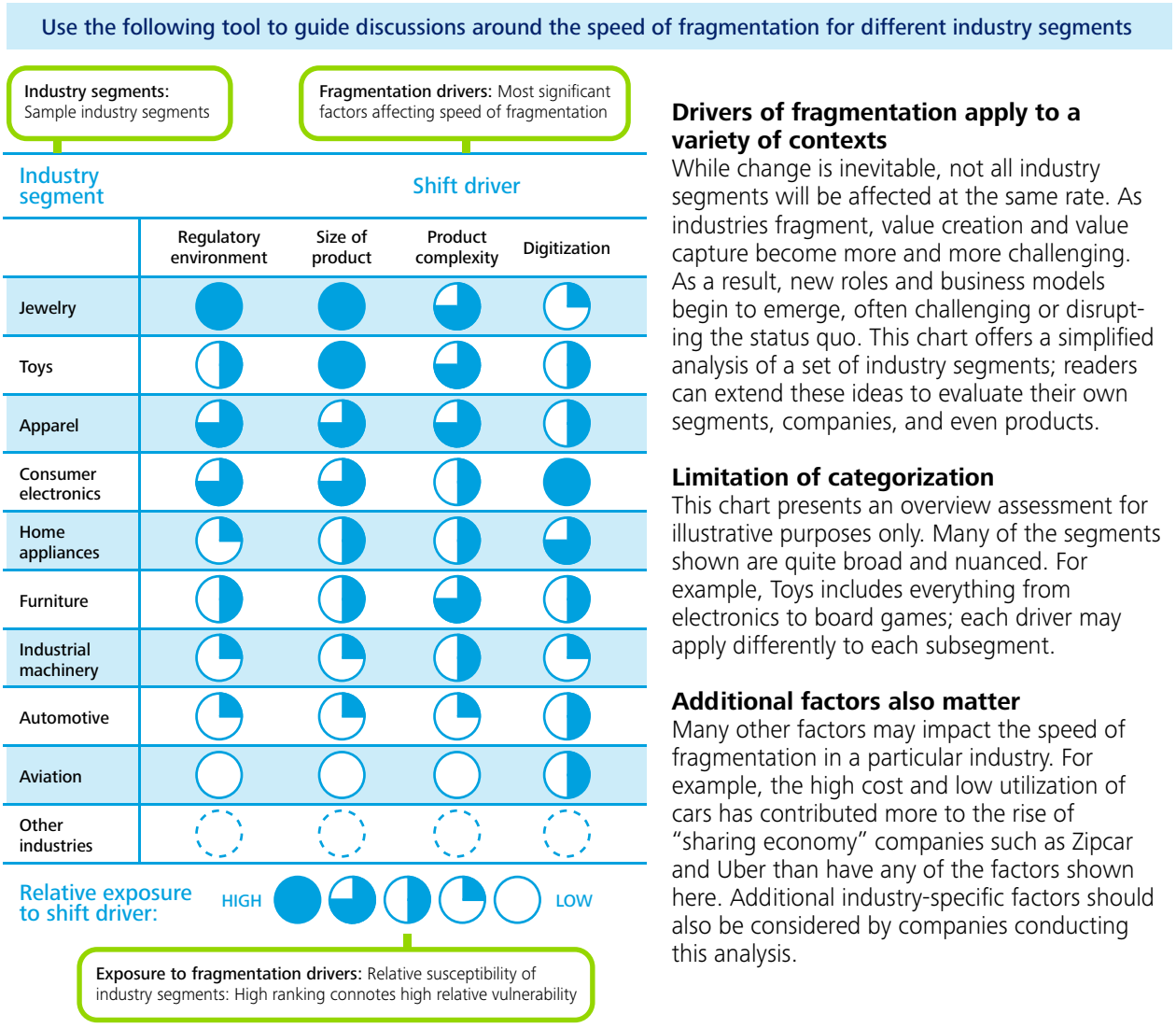
However, increasing product modularity plus new manufacturing processes can drive shifts in product size from large to small. The

Tata Nano, India's $2,000 "affordable car," was designed to be flat-packed and shipped for assembly close to the delivery point. Local Motors' Rally Fighter can be purchased either as a fully assembled car or as a kit for self-assembly. Size, it turns out, is not always a static measure.

Digitization

The "more digital" a product or industry is—the more sensors and electronics it incorporates, or the more digitized its processes—the shorter its product cycles. Technology is evolving at a faster pace each year—Products contain more and more digital technology, and so become obsolete more and more rapidly. With the greater use of digital manufacturing tools, an increasing number of physical objects being digitized, and a growing number of processes digitally transmitted and managed, the speed of evolution and collective learning increases, in turn speeding the fragmentation process. Consumer electronics and mobile phones have experienced this acceleration, facing ever-shorter product life cycles as a result. One counterpoint: If the software and applications on a product add more value that the product itself, it lengthens the product

Figure 6. Industry fragmentation assessment framework



Drivers of fragmentation apply to a variety of contexts

While change is inevitable, not all industry segments will be affected at the same rate. As industries fragment, value creation and value capture become more and more challenging. As a result, new roles and business models begin to emerge, often challenging or disrupting the status quo. This chart offers a simplified analysis of a set of industry segments; readers can extend these ideas to evaluate their own segments, companies, and even products.

Limitation of categorization

This chart presents an overview assessment for illustrative purposes only. Many of the segments shown are quite broad and nuanced. For example, Toys includes everything from electronics to board games; each driver may apply differently to each subsegment.

Additional factors also matter

Many other factors may impact the speed of fragmentation in a particular industry. For example, the high cost and low utilization of cars has contributed more to the rise of "sharing economy" companies such as Zipcar and Uber than have any of the factors shown here. Additional industry-specific factors should also be considered by companies conducting this analysis.

Source: Center for the Edge

Graphic: Deloitte University Press | DUPress.com

life cycle, since the software helps keep the product relevant.

As more "dumb" products become "smart," digitization is reaching once-dumb manufactured products. The advent of categories such as wearables, connected cars, and smart lighting is likely to speed obsolescence as the technology in these products ages faster than the products themselves.

Considering regulation, size, complexity, and digitization, and the movement of these factors in an industry, can help companies estimate the speed and intensity of coming shifts. The resulting estimates can help companies choose the best ways to participate in, and influence, the shifting manufacturing landscape. How fast is your industry or product segment fragmenting? Which factors—from regulatory environment to digitization—are driving that evolution? In the face of constant change, companies tend to step back and take a "sense and react" approach, watching the factors driving change and preparing themselves to react to new market conditions. Now, however, leaders have the opportunity to use deep understanding of these drivers to anticipate potential changes. They can then move their business in a direction both congruent with market forces and designed to position their company favorably.

Focus on the most promising business types

The ability to create and capture value will vary depending on the type of business. As discussed previously, the increasing demand for personalization and customization is poised to increase market fragmentation, while making it increasingly difficult for any single company to sustainably meet all of the consumer's needs. The companies that do the best job of capturing value will be those that figure out how to work with, and use, fragmentation rather than fighting it. Scale will move upstream to components and platforms, while scope (via a greater diversity of assemblers) will move downstream, owning the "last mile" to the customer.

We delve into these structural elements in much more detail in our paper *The hero's journey through the landscape of the future*.[81] Here, we present an overview of the coming landscape with a focus on manufacturing, in order to help participants determine which business roles might be most appropriate for them.

Both incumbents and new entrants should be aware of possible roles in this system, and each business should determine the best fit based on its assets, strengths, and core DNA as a corporation. In general, large companies are well suited to take on infrastructure management or customer relationship roles, while smaller companies are best positioned to play as niche product and service businesses. Entities looking for sustained growth may not be able to achieve it in the more fragmented downstream landscape, but will need to shift upstream to achieve their growth goals.

As product innovation, design, and assembly fragment, other parts of the business landscape will consolidate where scale and scope make it easier to support the niche operators. Areas of concentration will be marked by players, tightly focused on a single business type or role, that can muster the significant level of investment required to enter or sustain marketplace position in that role, and that generate value by leveraging resources such as large-scale technology infrastructure or big data to provide information, resources, and platforms to more fragmented businesses. Because these areas of concentration are driven by significant economies of scale and scope, early entrants that can quickly achieve critical mass are likely to gain a significant competitive advantage. Businesses that choose to focus on one of these roles are advised to be early movers rather than fast followers.

We anticipate scale-and-scope operators to fall into three broad business roles:

- Infrastructure providers
- Aggregation platforms
- Agent businesses

Infrastructure providers deliver routine high-volume processes requiring large investments in physical infrastructure, such as transportation networks (e.g., UPS and FedEx) and scale manufacturing plants (e.g., as Flextronics and Foxconn). Infrastructure providers also exist in digital technology delivery (e.g., Amazon AWS and Cisco) and scale-intensive business processes (e.g., Infosys and Wipro).

In the second category are **aggregation platforms**—virtual and physical platforms that foster connections, broker marketplaces, or aggregate data. For example, online marketplaces such as eBay and Etsy connect buyers and sellers; Kickstarter delivers financing by connecting artists, makers, and innovators with their fans; and Facebook connects people socially to share knowledge or information.

The third category encompasses the role of **agent**. The consumer agent, a trusted advisor that helps consumers navigate an array of possible purchases, is the agent type most relevant to the manufacturing landscape. While agent businesses have always existed—from wealth managers to personal shoppers—their customer base has been mostly the affluent. Now, however, technology is making such services more widely available to the general population. In manufacturing, fragmentation in the area of final product assembly will give rise to agents that guide retail consumers to the right options for them. The retailers most likely to survive and thrive are those that embrace this role, becoming experts dedicated to supporting each consumer's unique needs.

The three roles above are based on scale and scope, making them attractive positions for companies looking to achieve significant and sustained growth. Businesses in these roles collaborate closely with the fragmented but focused niche players.

In the resulting ecosystem of niche players supported by scale-and-scope businesses, "mobilizers" are the connective tissue that organizes an ecosystem to move in specific directions. Mobilizers can add value by framing explicit motivating goals, providing governance that enhances interactions, and facilitating collaboration. Maker Media's Maker Education Initiative (slogan: "Every Child a Maker") is a good example of a mobilizer framing an explicit goal. In addition to its rallying cry to increase maker education, the group publishes programs and playbooks designed to provide governance and facilitate collaboration.

It is not surprising for these roles to emerge in response to the shifts in the manufacturing landscape described earlier. Each role represents an essential business type. For example, fragmented niche operators are **product** businesses, focused on designing and developing creative new products and services, getting them to market quickly, and accelerating their adoption. This business type is driven by the economics of time and speed to market. It requires skills and systems focused on rapid design and development iteration, supporting the quick identification and addressing of market opportunities. The culture of this type of business prioritizes creative talent and is oriented toward supporting creative stars.

Infrastructure providers and **aggregation platforms** are examples of **infrastructure management** businesses. This business type is driven by powerful scale economics. It requires skills to manage routine high-volume processing activities, and has a culture that prioritizes standardization, cost control, and predictability. In this business culture, the facility or asset trumps the human being.

The agent role is an example of the **customer relationship management business** type, which is driven by economics of scope—building broader relationships with a growing number of customers. The more this business type knows about any individual customer, the more accurately it can recommend resources to that customer. Simultaneously, the more it knows about a large number of customers, the more helpful it can be to any individual based on its ability to see larger patterns. To succeed, such businesses need to understand the evolving context of each customer based on carefully structured interactions, plus a growing data set that captures context and history.

The culture of this business type is relentlessly customer-focused—seeking to anticipate needs before they arise, building trust, and positioning the business as a trusted advisor rather than a sales-driven vendor.

Aiming to become infrastructure management or customer relationship businesses can help large companies leverage existing economies of scale and scope to occupy the concentrating portions of the business landscape. Smaller companies, in contrast, are best served by aiming to become a product/service type of businesses, filling in the more fragmented portions of that landscape.

Today, most large companies operate multiple types of businesses (and thus play multiple roles) within a single organization. Given the uncertainty of a rapidly changing world, such diversity is often viewed as a strategic advantage; a portfolio is comforting. However, when a company participates in too many business types at once, it can lack focus. Diverse groups compete for resources, chafe under inappropriate economics or metrics, and clash culturally. The reality is that the three business types bundled into today's large enterprises have very different economics, skill sets, and cultures.

In the past, large companies bundled these business types together because of the high cost and complexity of coordinating activity across independent companies. However, today's ever more powerful digital infrastructure makes it far less expensive, and far easier, to coordinate activity across a growing number of independent entities. As competitive pressure intensifies, companies that keep the three business types tightly bundled will likely reduce performance as they seek to balance out the competing demands of these business types. Such businesses can become more vulnerable to companies that, by focusing on a single business type, become world-class in their chosen activities.

Further, as the pace of change accelerates, the imperative to learn faster becomes more pronounced. A company that focuses on a single business type is likely to learn much faster without the distraction of multiple competing businesses within its walls. It is more likely to attract and retain world-class talent, gaining employees seeking to be the heroes of the organization rather than take on second-class support roles. Its learning potential can be further enhanced by the ability to connect and collaborate with trusted top-tier companies of the other two types.

To flourish in an increasingly competitive environment, a company should resist the temptation to do everything. Instead, it should put its energies into one primary role. Given the divergent drivers, cultures, and focuses of the three business types, an organization that contains more than one can benefit from first separating them operationally within the firm. Then, over time, it can choose a primary type to prioritize as its company's core DNA, ultimately shedding operations in the other two business types completely. Perhaps paradoxically, such unbundling can set the stage for much more sustained and profitable growth.

Large incumbents may be understandably reluctant to let go of their current positions in the value chain. But failing to adapt to the new landscape is missing a powerful opportunity to own an influential new position in that chain—a foundational platform on which a large number of smaller players build. If this role is played out correctly, a new ecosystem of smaller, specialized niche providers will form around the large incumbent to customize and personalize products (through physical products, software, or services). All of these will be tied together by an entirely new set of players—mobilizers, data platforms, and connectivity platforms.

Pursue leveraged growth opportunities

Historically, to achieve growth, entities had two options: buy or build. Advances in digital technology and connectivity allow for a third option, "leveraged growth," in which a business can connect with and mobilize a growing array of third parties in the fragmenting parts of the

manufacturing landscape to create and capture value for its customers. Companies occupying the platform, infrastructure, and agent roles, which are inherently positioned for growth, can accelerate that growth and gain flexibility by leveraging trusted resources from outside their organizations. In addition to financial resources, such players can leverage the capabilities of its third-party partners. By doing so, they reduce risk, broaden their perspective to maximize learning and performance, and cut costs by taking advantage of existing resources. Just as important, they build a network of trusted relationships, a factor becoming more and more crucial in navigating the future manufacturing landscape.

This level of transformation is very much in the domain of larger businesses—whether incumbent or entrant—with the resources to influence market factors. These businesses will be doubly successful if they develop strategies—and platforms—that allow them to attract and support a large number of smaller, more fragmented players. Leveraged growth can also help the larger business sense the shifting environment more accurately, and continue to shape it.

In turn, smaller firms can leverage platform businesses for financing, learning, and prototyping, reducing capital investment while increasing speed to market. They can address surges in demand by relying on infrastructure providers, and can more effectively connect with relevant customers through agent businesses. Though they may have little power to move the market individually, they can maximize their influence as part of a broader ecosystem.

Two potentially promising business models emerging in the manufacturing landscape can enable leveraged growth for large incumbents: the shift from **products to platforms** and from **ownership to access**.

As digital and physical products become platforms, they enable a wide variety of participants to join, collaborate, and innovate. Platforms have a tremendous network effect, growing in importance as more participants join and thus extend their functionality. They are also a cheaper, more flexible, and less risky way for participants to enter a space. Once platforms gain traction and achieve a critical mass of participants, they become hard to replace.

The shift from ownership to access allows manufacturers to transform their focus from making products to developing deep, long-term customer relationships. At the core of this shift is a platform that aggregates resources and enables consumer access. With it, consumers can access products as they need them. Manufacturers can use data collection and product use feedback to continually grow and improve. And as access providers gain a deeper knowledge of customers and their needs, they can identify and mobilize a broader range of third parties to enhance the value provided to customers.

Identify and, where possible, occupy emerging influence points

There are still more ways to capture value in the rapidly shifting manufacturing landscape. With eroding barriers to entry and continued exponential growth of the digital infrastructure, many companies are seeing their positioning weaken. Strategic positions in the value chain—or influence points—are shifting. These positions are often key to enhancing value-capture potential. Power once derived from harboring stocks of knowledge now arises from an organization's position in the flow of knowledge. While patents and intellectual property remain valuable, their strategic significance is declining as the pace of innovation increases and product life cycles shrink. New influence points are instead emerging around flows of knowledge. Privileged access to these flows makes it possible to identify and anticipate change before others do, and to shape them in a way that strengthens future positioning. Access to these diverse flows can also speed up learning—the key to competitive advantage in a quickly evolving market.

GE FIRSTBUILD: BIG COMPANIES BEHAVING NIMBLY

In February 2015, GE launched its first crowdfunding campaign on Indiegogo. The Paragon Induction Cooktop is a Bluetooth-enabled tabletop cooker created by GE subsidiary FirstBuild—and the test case for the company's new manufacturing model. The campaign met its $50,000 funding goal in less than 24 hours and tripled it by the end of the day, reaching a total of nearly $300,000 at the time of publication.[82]

Funders and consumers may ask what a GE subsidiary is doing looking for crowdfunding. The answer has to do with the way products are developed at GE. The company excels in scale and lean manufacturing and is very good at producing high product volume at a low price. Product innovation and development, however, is another story. Where Indiegogo's base of makers and small-scale entrepreneurs have speed on their side, large companies like GE can take two to three years to bring a new product to market, making it hard to keep up with market demands. It's a perennial problem, and one common among large firms.

In 2014 Kevin Nolan and Venkat Venkatakrishnan came up with a solution: a combined online and physical co-creation community for makers, designers, and engineers. The idea for FirstBuild came about when GE asked itself two simple questions: Why did it take so long to develop new products, and why could smaller hardware entrepreneurs develop them so much more quickly? The answer was equally simple: To build products quickly, GE needed to test more ideas with more people more frequently. It needed a system combining the capabilities of a large manufacturer and a lean startup.

For FirstBuild, an Indiegogo launch complemented GE's existing product development capabilities in several ways. Crowdfunding locks in sales before a product enters production, allowing for incredibly accurate demand forecasts and resulting manufacturing choices. If a campaign generates only a few pre-orders, FirstBuild can use a small manufacturing partner to produce the necessary units, then discontinue production without losing money on a larger effort. A hit like the Paragon can ensure big sales, and FirstBuild can leverage GE's massive manufacturing capabilities to produce the needed units, avoiding stock outs. In both cases, crowdfunding generates immediate viability feedback before production, allowing the company to build to order. Crowdsourcing also helps FirstBuild guarantee minimum product revenue before launch; selling a crowdfunding campaign's minimum number of units can fund some or all of a product's fixed production costs.

FirstBuild also acts as a test lab for shifts in the future manufacturing landscape. Integrating community into design, building, and sales directly addresses changing consumer needs. The Paragon cooker introduces smart cooking and integrated test software platforms and apps. By applying agile prototyping and tapping into the Chinese manufacturing ecosystem, FirstBuild is testing the shifting economics of manufacturing. And by selling directly to customers and building to order, it is shifting the economics of the value chain.

In entering a space formerly inhabited by startups and individual makers, GE is changing the game for product development across the board—dramatically cutting development time and cost while insuring against large-scale failure. The effects on the industry are sure to be both fast and far-reaching.

So how do influence points emerge and evolve? They attract participants through the value they provide, and inspire action with positive incentives. Influence points are most likely to emerge where they can provide significant and sustainable functionality to the broader platform or ecosystem, where their functionality can evolve rapidly, where network effects drive consolidation and concentration of participants, and where they can encourage fragmentation of the rest of the platform or ecosystem. For example, in the early days of the personal computer industry, development of de facto standards for microprocessors and operating systems encouraged significant fragmentation in other aspects of the technology. These standards also created concentrations in knowledge flows as companies sought to connect with makers of the standard technologies to understand how they were likely to evolve.

Another example of shifting influence points is the ongoing value shift from **physical products** to **digital streams created by smart products**. As products become more digitized, value shifts from the product itself to the stream the product enables. Here the greatest knowledge flows may have little to do with specific products; instead, they become part of the emerging IoT infrastructure. Such shifts tend to create new influence points further from the core capabilities of current manufacturing incumbents—points that favor large external players such as Google, Facebook, Apple, and Amazon. Google's acquisition of home IoT device company Nest and Facebook's acquisition of virtual reality startup Oculus VR make a lot more sense in this context—as do Google's Android, Apple's iPhone and iPad, and Amazon's Kindle devices.

As the manufacturing landscape and value chain evolve, old influence points will erode and new ones emerge. For established incumbents, doing nothing in this area is likely to lead to loss of influence and an erosion in the ability to capture value. To maintain or extend current levels of influence, manufacturers should evaluate their value chains, identifying current influence points and possible changes that could affect their position. Next, they should identify potential new influence points where they might establish strongholds. This may mean releasing elements once central to a firm's value, and reimagining value in the context of potential positioning in the value stream.

Big firms—both incumbents and new entrants—have an advantage here, as they tend to have resources valuable to a large number of fragmented players. Patent portfolios can be seen as a means to increase and focus knowledge flow, rather than as a static stock of knowledge or barrier to entry. GE took this path when it gave Quirky community members access to GE patents, encouraging innovation outside the initial patent domain.

Clearly, not everyone can target and occupy influence points; by definition, there are only a few to be had, and doing so is not required for success. But businesses that can control influence points can create more sustainable advantages and get advance information about evolving markets.

When navigating the path to enhanced value creation and value capture, a business should first determine how these ideas apply to its particular industry and its position within it, as well as to its organization and the products it produces. The next step is to determine the roles with the greatest potential for growth, exploring how it might shift to occupy one or more of those roles. Finally, the company should look for opportunities to collaborate with other players, large and small, in the relevant ecosystem—and determine how it might occupy emerging influence points. Given the ever-changing nature of the manufacturing landscape, such exploration and evolution are an ongoing process, one that businesses must continually follow if it wants to stay relevant.

Conclusion

THE manufacturing landscape is undergoing a massive collective shift. Consumer demands, the nature of products, and the economics of production and distribution are all evolving. Boundaries are blurring between manufacturing and technology on one hand and manufacturing and retail on the other. While more value is being created, manufacturers are under increasing pressure. In this environment, capturing value requires fundamentally rethinking business models—remapping a company's strategic positioning based on internal capabilities, external shifts, and emerging influence points.

Several large incumbents are making moves in these directions. GE Aviation moved from selling jet engines to selling power by the hour, as a utility company would. And savvy start-ups are developing business models in alignment with the new manufacturing landscape. Xiaomi started with a direct-sales model that prioritized consumer relationships, then eventually expanded to include traditional retail channels. The company knew that the influence point was closeness to the consumer; owning that space allowed it to develop good terms with retailers.

The manufacturing landscape is facing dramatic changes. Creating and capturing value in this new environment will require understanding the factors driving change in specific manufacturing sectors, focusing on activities that convey a structural advantage, leveraging the skills and capabilities of third parties, fundamentally rethinking business models, and identifying influence points. There is no one path to success; instead, we offer a set of pointers and guideposts. Take this opportunity to define your own success—and blaze your own trail through the new landscape of manufacturing.

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Mark Cotteleer

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Eric Pan
Violet Su
Jia Dong
David Li
Mark Hatch

Contacts

For more information about this report or about the Center for the Edge, please contact:

Blythe Aronowitz
Chief of staff, Center for the Edge
Deloitte Services LP
+1 408 704 2483
baronowitz@deloitte.com

Wassili Bertoen
Managing director, Center for the Edge Europe
Deloitte Netherlands
+31 6 21272293
wbertoen@deloitte.nl

Peter Williams
Chief edge officer, Centre for the Edge Australia
+61 3 9671 7629
pewilliams@deloitte.com.au

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The Deloitte Center for the Edge conducts original research and develops substantive points of view for new corporate growth. The center, anchored in Silicon Valley with teams in Europe and Australia, helps senior executives make sense of and profit from emerging opportunities on the edge of business and technology. Center leaders believe that what is created on the edge of the competitive landscape—in terms of technology, geography, demographics, markets—inevitably strikes at the very heart of a business. The Center for the Edge's mission is to identify and explore emerging opportunities related to big shifts that are not yet on the senior management agenda, but ought to be. While Center leaders are focused on long-term trends and opportunities, they are equally focused on implications for near-term action, the day-to-day environment of executives.

Below the surface of current events, buried amid the latest headlines and competitive moves, executives are beginning to see the outlines of a new business landscape. Performance pressures are mounting. The old ways of doing things are generating diminishing returns. Companies are having a harder time making money—and increasingly, their very survival is challenged. Executives must learn ways not only to do their jobs differently, but also to do them better. That, in part, requires understanding broader changes to the operating environment:

- What is really driving intensifying competitive pressures?
- What long-term opportunities are available?
- What needs to be done today to change course?

Decoding the deep structure of this economic shift will allow executives to thrive in the face of intensifying competition and growing economic pressure. The good news is that the actions needed to address short-term economic conditions are also the best long-term measures to take advantage of the opportunities that these challenges create.

For more information about the Center's unique perspective on these challenges, visit www.deloitte.com/centerforedge.

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