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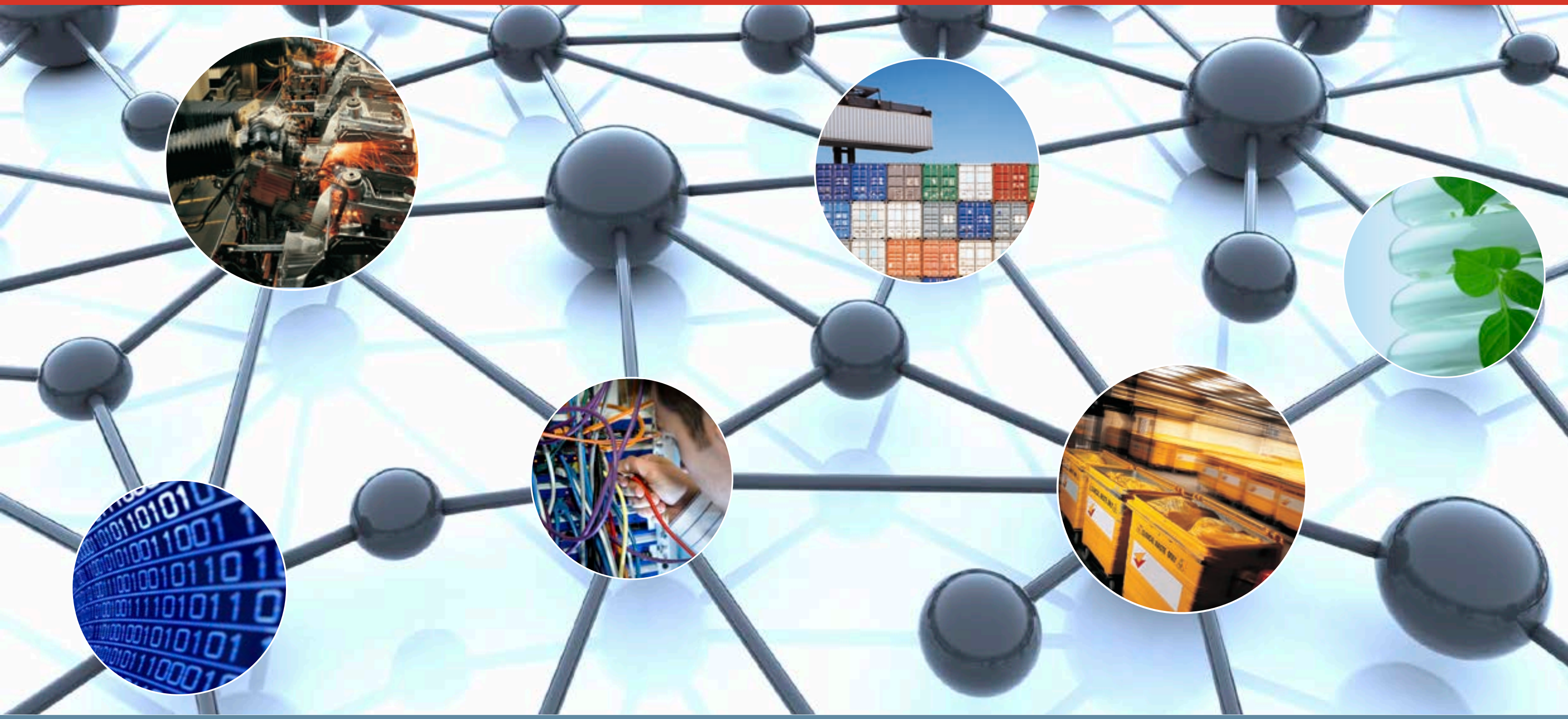

21ST CENTURY manufacturing

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

BRIE

21st century manufacturing

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2013

This publication has been produced by the United Nations Industrial Development Organization (UNIDO) under the general guidance of Ludovico Alcorta, Director, Development Policy, Statistics and Research Branch. The author(s) of each individual chapter are indicated.

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This report was prepared under the general guidance of Ludovico Alcorta, Director of the Development Policy, Statistics and Research Branch of UNIDO. The contributors to the report are John Zysman, Dan Breznitz, Martin Kenney, Stuart Feldman, Jonathan Murray, Niels Christian Nielsen, Kenji Kushida and Paul Wright. The affiliation of each author is indicated in the respective chapter(s).


CLINICAL WASTE ONLY

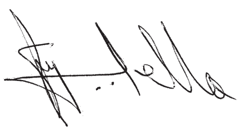
Foreword

The manufacturing sector, being the cradle of innovation and technical change, has always occupied an extraordinary position in the minds of economic policymakers. The majority of innovations are introduced first and commercialized in this sector, making it the main engine of technical change and economic growth.

Technological change, in turn, is a crucial driver of competitiveness in the manufacturing industry, and is thus of particular interest for both business leaders and policymakers. In order to be able to design and implement policies that can support the growth and enhanced performance of the manufacturing sector of their respective countries, it is important for the policymakers concerned to have the necessary knowledge of how such technological change can be supported and promoted.

This publication is part of a series published by UNIDO to provide insights into current and future global trends that will influence manufacturing production in developing and developed countries in the years to come. It aims to assist policymakers in designing and implementing policies that can help their industries and countries gain a competitive edge in international markets.

I sincerely hope that the insights contained in this publication will be of value for policymakers, scholars and business leaders as they anticipate and adapt to the main forces shaping the manufacturing sector. At the same time, I invite the readers to actively participate in the discussion on the future of the manufacturing industry, which this publication series seeks to promote, and to contribute their experiences and opinions to the debate.



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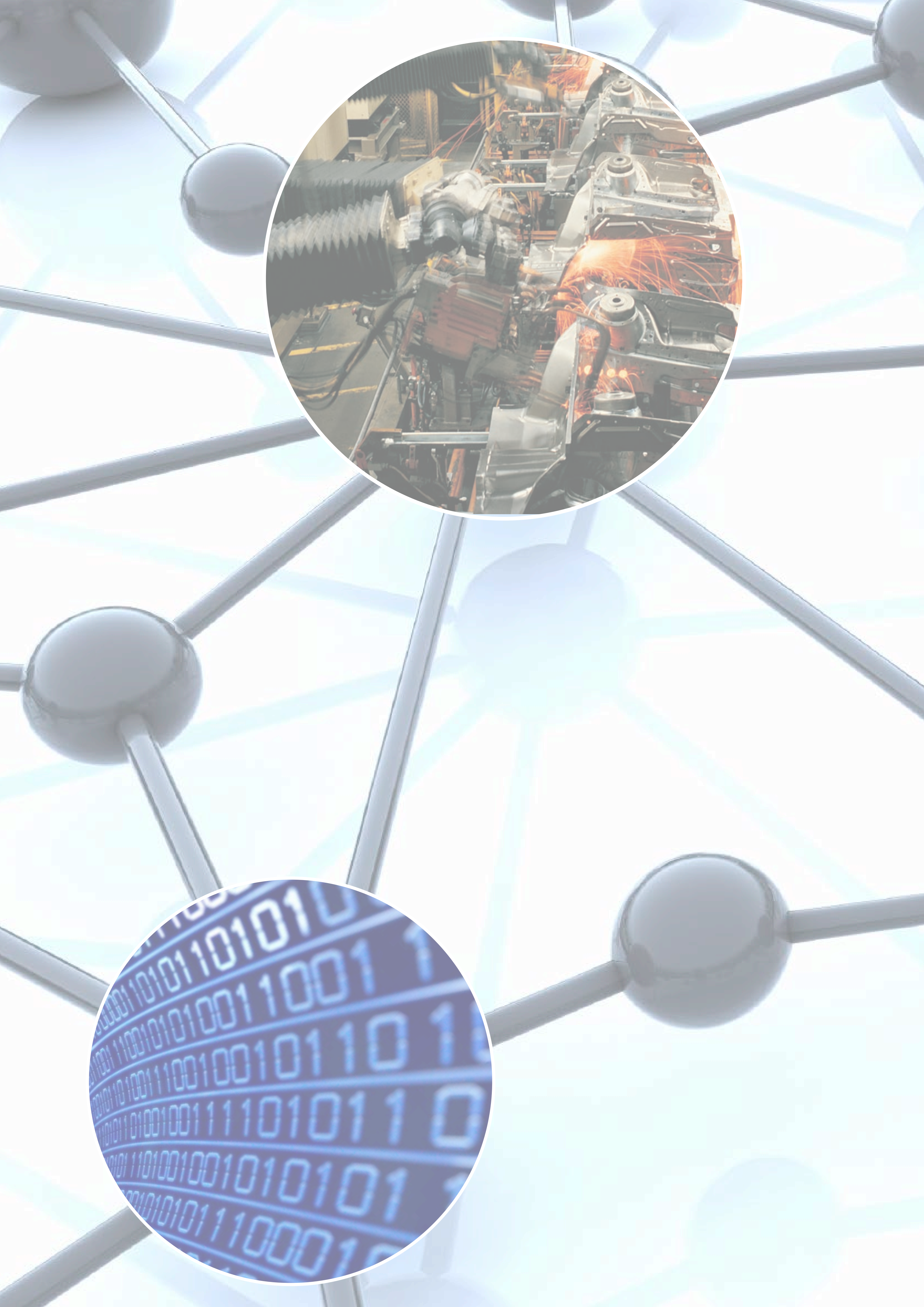

Contents

I. Introduction: manufacturing transformed

John Zysman[1] *and Dan Breznitz*[2]

A. Manufacturing transformed

Manufacturing in the twenty-first century remains a key element of economic growth, trade, productivity and development. However, the questions and issues that arise in the twenty-first century are quite different from those at the end of the twentieth. The "who, what, where and how" of manufacturing throughout the world have been transformed over these past decades.[3] Manufacturing has been fundamentally changed by the decomposition and modularization of production, the emergence of ICT (information and communications technology)-enabled services embedded in physical products, the entrance of new competitors, and the continuing development of production technology. The genesis of today's goods—from aircraft to apparel—is now an international affair. This report depicts and considers aspects of those changes to highlight some of the choices facing firms and government.

Four issues emerge from this analysis of particular importance for Latin American countries and firms as they try to find their place of advantage in global markets: *(a)* Asia has become a production hub for firms serving the American and European markets as well as the expanding Asian markets. China's growth as an exporter is reorganizing the global flow of production, putting ever greater competitive pressure on Latin American firms; *(b)* the decomposition of production and a corresponding geographic redistribution of activity have meant increasing commoditization—that is, increasing competition based principally on price. It will be difficult to build market advantage, let alone economic development, based principally on price advantage rooted in wage differentials; *(c)* the advanced industrialized countries, and advanced industrialized country producers, are creating advantage and escaping commoditization through advanced manufacturing and ICT-enabled services. Drawing on, applying, and, where possible, contributing to those developments in ICT-enabled services and advanced manufacturing will be ever more crucial for Latin American countries; and *(d)* competition will increasingly be organized around phases of production, such as design or scale

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[2] Danny Breznitz is an associate professor at the Georgia Institute of Technology and program director of Globalization, Innovation, and Development at the Sam Nunn School of International Affairs, Georgia Tech.

[3] Zysman explores these concepts in earlier works: S.S. Cohen and J. Zysman, *Manufacturing Matters: The Myth of the Post-Industrial Economy* (New York: Basic Books, 1987); J. Zysman, "Strategic Asset or Valuable Commodity? Manufacturing in a Digital Era," paper presented at "New Directions in Manufacturing," Forum of the National Academies of Science, March 2003, published in New Directions in Manufacturing (Washington, D.C.: National Academies Press, November 2003)..

manufacture, rather than just around sectors, such as electronics or automobiles. Countries and regions will have to develop pools of competencies to succeed in phases, not just defend or develop sectors. That will require all countries to rethink industrial strategies.

This report proceeds in the following five steps:[4]

- Who produces what and where? For firms, whether buyers or sellers, the crucial question is whether a product, a constituent element of the product, or a simple component is a strategic asset or a simple commodity. That is, whether it is a strategic asset that must be developed or produced in-house, owned but developed or produced by another firm, or a simple commodity that can be obtained on the market. The answer is constantly changing as a reflection of the characteristics of the products and components, of the tools available, and the business problems facing firms. For producers, the question is how to find a distinctive spot in the market. For places, the question is where they fit in the value network and what must be done to allow local producers to succeed in global market competition. If the data concerning the trade of intermediate goods is overly aggregated, how can we begin to properly identify where the value of products is or how it is being dispersed? We address that problem in the next section.

- Where is the value in the value networks? Trade statistics do not capture fully the transformation. For example, while some or even large portions of the jobs may be moving outside the advanced industrialized countries, much of the value has stayed there. Trade statistics do not allow us to consider who (which firms) produces what (products or components) for whom or where. Consequently, it is difficult to untangle the implications of globalization, decomposition of production, the unbundling of services, and indeed the character of the changing competitive environment. To overcome this deficiency, chapter II explores, across a set of sectors, the question of where the value lies and explores the question of who produces what for whom.

- Services, ICT-enabled services, now come with everything. One reason that value stays in the advanced industrialized countries rests, increasingly, with the role of ICT-enabled services embedded in products, as John Zysman and his colleagues discuss in chapter II. The algorithmic revolution has changed not only the services sector but the character of competition, product development and production in manufactured goods as well.

[4] Prepared by Martin Kenney, professor at University of California, Davis and senior project director, at BRIE; John Zysman, professor at University of California, Berkeley and co-director of BRIE; Dan Breznitz, associate professor at Georgia Tech, and program director, Globalization, Innovation, and Development; Paul Wright, professor of mechanical engineering at University of California, Berkeley, director of the Center for Information Technology Research in the Interest of Society (CITRIS). Discussion based on M. Kenney and B. Pon, "Structuring the Smartphone Industry: Is the Mobile Internet OS Platform the Key?" *Journal of Industry, Competition and Trade* 11, no. 3 (2011): 239-261; D. Breznitz & M. Murphree, *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China* (New Haven: Yale University Press, 2011); D. Breznitz, *Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan, and Ireland* (New Haven: Yale University Press, 2007). Zysman draws on work done with Stuart Feldman, Kenji Kushida, Jonathan Murray and Niels Christian Nielsen.

Phrased differently, the value of an object lies increasingly with the digitally enabled services that it can provide.

- Increasingly, analytic focus must be on phases of production, rather than sectors of production. Our understanding of the organization and dynamics of manufacturing, as Breznitz shows in chapter IV, has changed. A generation ago, we talked about Toyota's competition with General Motors and the emergence of the Toyota just-in-time production system. Now the focus is on how Foxconn in Shenzhen, China, represents a phase in a production process that begins with new conceptions and designs by Apple, for example, in Cupertino, California. We know that the clustering of design activities in Silicon Valley makes it easier to innovate, and, likewise, we know that the clustering of metal cutting, circuit board assembly, component manufacturing, plastic injection molding tooling, and the ability to mobilize tens of thousands of people very quickly make it easier to scaleup production in Shenzhen.

- Where and how goods are produced has been transformed by an array of technological developments. The face of manufacturing promises to change with the emergence of additive manufacturing, popularly labeled 3D printing, and robotic factories. While labour-intensive production persists, labour costs are not always the crucial element in the advanced countries, and often not in emerging markets. For instance, new advanced manufacturing technologies can be used in contradictory ways. One option, famously idealized as the German model, is by making skilled labour more productive. An opposite strategy aims to put all the "brain" in the machine in order to allow the employment of cheap and easily replaceable unskilled labour. Many of these changes depend on the specific environment in which the technologies are applied. How do we begin to conceptualize these changes?

B. Brief background

The basic trends in the global economy are well understood. As we begin, we simply need to remind ourselves of them. For our purposes in this story, the key point is that the "production" of goods and services is no longer organized in vertically integrated companies focused on home locations.[5] This process of decomposition has been underway and understood for some time.[6] The ICT industries have been at the forefront of this transformation of work organization, while also producing the tools that facilitated the decomposition of production. As is widely discussed in the case of manufacturing, companies have broken

[5] This material draws on J. Zysman and D. Breznitz, "Double Bind: Governing the Economy in an ICT Era," *Governance 25*, no. 1 (2012): 129-150.

[6] S.W. Arndt and H.Kierzkowski (eds.), *Fragmentation: New Production Patterns in the World Economy* (Oxford: Oxford University Press, 2001); P. Hirst and J. Zeitlin, "Flexible Specialization Versus Post-Fordism: Theory, Evidence and Policy Implications," *Economy and Society 20* (1991):1-56; C. Sabel. "Flexible Specialization and the Reemergence of Regional Economies," in *Post-Fordism: A Reader*, ed. Ash Amin (Malden, MA: Blackwell, 2004): 101-156.

apart the production of their input components, from research down to final assembly, and source them both internally and externally throughout the world.[7]

For our purposes, decomposition refers to the geographic and organizational recasting of operations from actual manufacturing through R&D and strategy. It refers to outsourcing, purchasing goods or services outside the boundaries of the particular firm, and offshoring, the moving of activities to a different country, whether internally within the company or using outside suppliers. The contemporaneous geographic recasting of production tasks across borders and its recomposition in a final product, have come to be known as supply networks. We use the notion of value networks or webs of components, modules, subsystems, and service bundles, as opposed to a simple value chain, to suggest the constant reorchestration and relocation of the components of value creation, and, importantly, the imaginative reintegration of the constituent elements. There is a constant reorchestration and relocation of the components of value creation, and, importantly, the imaginative reintegration of the constituent elements. As we consider later, just as manufacturing has been decomposed, so have many ICT-enabled services been unbundled and redistributed geographically and organizationally. The basic fact of the decomposition of production, and its constant recomposition, rather than the particulars, is crucial for our purposes here.

Certainly, the decomposition of production has long been underway. The dominant tendency in contemporary production may be decomposition, but in some cases, a powerful recomposition can also be discerned. For example, many of the largest logistics firms, such as Fedex and UPS, have integrated more and more logistics services internally. Previously, shipment and customs clearing were handled by separate firms. Today, FedEx and UPS have integrated these two services. Similarly, whereas previously IBM or Oracle sold software, now they not only offer customers software but manage their entire IT system to the point of providing dedicated call centres.

Foxconn, while allowing firms such as Apple, Dell, HP and Motorola to shed some manufacturing activities and therefore decompose their value networks, also is recomposing the value network. To illustrate, under its parent company, Hon Hai Precision Industry, it makes components such as camera lenses, connectors, cables, enclosures, plastic injection molded parts, power supplies, printed circuit boards and sensors, for use in industries ranging from electronics to automobiles. Not only does it provide manufacturing services, but it also offers design services. It is, in fact, a value network integrator. In effect, much of this may be about who integrates what and for what reasons. Different business models and insertions into the network may allow different value capture strategies.

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[7] J.T. Sturgeon, "Turnkey Production Networks: The Organizational Delinking of Production from Innovation," in *New Product Development and Production Networks* (New York: Springer, 2000), 67-84; J.T. Sturgeon, "Modular Production Networks: A New American Model of Industrial Organization," *Industrial and Corporate Change* 11, No. 3 (2002): 451-496.

From the aggregate data, it is simply not possible to follow this story; much of what we know comes from more finely grained studies of places and sectors.[8] Many of those studies are referenced in the chapters that follow. First, however, let us remind ourselves for a moment what the aggregate data does tell us. The indicators in the aggregated data successfully reflect the basic changes in the structure of global production over the past several decades: the proliferation of foreign direct investment (FDI), the increase in trade as a percentage of the gross domestic product (GDP), and the increase in manufacturing exports, among others. It speaks of a shift in global export prominence away from the United States and Europe and towards the rise of new players such as China and India.

FDI has increased dramatically as multinational corporations (MNCs) have spread production around the globe and international trade has increased dramatically. Consider total volumes of FDI. In the past several decades, United Nations data has tracked the exceptional growth of worldwide FDI; the sum of these capital flows were US$ 27 billion in 1977, US$ 133 billion in 1987, US$ 485 billion in 1997, US$ 1.97 trillion in 2007 before the most recent global recession, and US$ 1.42 trillion in 2011, a modest rise after the large declines of 2008 and 2009. Certainly, and in parallel, trade as a proportion of national GDP has increased significantly. According to data from the United Nations,[9] this proportion increased from 30.57 per cent in 1988 to 37.07 per cent in 1998 to 55.9 per cent in 2011—a 25 percentage point increase in 23 years. The value of world merchandise exports increased exponentially in the past several decades, doubling from US$ 1.83 trillion in 1983 to US$ 3.68 trillion in 1993. This doubling trend continued as the value of world exports reached US$ 7.38 trillion in 2003 and then accelerated to US$ 15.2 trillion only eight years later in 2011.[10,11]

Our focus in this report, of course, is manufacturing. The global export of manufactured goods has steadily risen in the past several decades. According to the World Trade Organization (WTO), total world exports of manufactured goods doubled from US$ 1.09 trillion in 1980 to US$ 2.39 trillion in 1990. In 2000, it reached US$ 4.69 trillion. And in 2010, total world exports of manufactured goods was valued at US$ 9.96 trillion. In a mere three decades, exports of manufactured goods grew by nearly an order of magnitude.

The geographic relocation of manufacturing in the past several decades is evident in the aggregated regional export data.[12] North America's portion of total world

[8] A clear exception to this is R. Hausmann and C. Hidalgo, "The Network Structure of Economic Output," *Journal of Economic Growth* 16 (2011): 309-342.

[9] United Nations Conference on Trade and Development, Foreign Direct Investment Online database, www.unctad.org/en/Pages/DIAE/FDI%20Statistics/FDI-Statistics.aspx, accessed May 2012.

[10] World Trade Organization, International Trade and Tariff Data: International Trade Statistics, 2011 Table 1.6, www.wto.org/english/res_e/statis_e/its2011_e/its11_ world_trade_dev_e.htm

[11] This tremendous increase of exports can also be broken down into three broad categories: manufactured goods, raw materials, and services. In this essay we explore only the manufacturing issues.

[12] World Trade Organization (2011). Table 1.6, www.wto.org/english/res_e/statis_e/its2011_e/its11_world_trade_dev_e.htm

exports decreased from 18 per cent in 1993 to 13.2 per cent in 2010. Meanwhile, the proportion of European exports declined from 45.4 per cent in 1993 to 37.9 per cent in 2010. Asian exports, meanwhile, increased from 26.1 per cent in 1993 to 31.6 per cent of the world total in 2010. Chinese exports alone grew from 2.5 per cent in 1993 to 10.6 per cent of the world total in 2010. By contrast, Latin America had a modest increase, from 3 per cent to 3.9 per cent of total global exports, over the same period. Brazilian exports increased from 1 per cent in 1993 to 1.4 per cent in 2010, while Argentina's exports increased from 0.4 per cent in 1993 to 0.9 per cent in 2012.[13] Note that although Latin American exports increase in absolute terms, they do not significantly alter the patterns of global manufacturing.[14] The shifts in export prominence clearly indicate the rise of new players in the world's various supply and value chains. New production titans, such as China, have become an essential element of today's competitive supply chains.

Global commercial service exports increased in the past three decades as well. As we see in chapter III, this is part of a trend in ICT-enabled services that changes the face of manufacturing. Assessing the pattern of exports of ICT-enabled services is extremely difficult for two reasons. The first reason is that the sale of equipment embedding sensor systems that provide services is listed as a manufactured "good," even when the sale is predicated on the larger provision of an information-based service. The second reason is that ICT-enabled services do not fall, in many cases, into the traditional categories of service exports. What we do know is that global commercial service exports were valued at US$ 367 billion in 1980. In 2000 the total value of exported commercial services grew to US$ 1.48 trillion and then US$ 3.69 trillion in 2010.[15] Despite these large reported increases in the export of services, it is not clear exactly what this tells us.

The proliferation of cross-national production networks in the past twenty years holds a variety of implications for advanced economies. First, although the manufacturing exports in advanced countries declined as a share of global manufacturing, total production still increased. According to the United States Bureau of Labor Statistics International Labor Comparisons,[16] between 1990 and 2010 total manufacturing output[17] increased in the United States from 67.6 to 113.8, in Germany from 94.5 to 103.6, in Japan from 98.9 to 117.6, and in Singapore from 51.2 to 181.[18] More important perhaps, manufacturing output per worker hour increased.[19] Between 1990 and 2010, manufacturing output per hour in developed countries increased dramatically. The United States increased from 58.1 to 147.1. Germany grew from 69.8 to 115.6, Japan rose from 70.9 to 136.2.

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[13] Ibid.

[14] Ibid.

[15] Ibid.

[16] U.S. Department of Labor, Bureau of Labor Statistics, International Labor Comparisons: Productivity and Unit Labor Costs in Manufacturing: Data Tables, 1950-2010. ftp://ftp.bls.gov/pub/suppl/prod4.prodsuppt03.txt

[17] Manufacturing real output is estimated using moving price weights, as recommended by SNA 93. U.S. Department of Labor, Bureau of Labor Statistics, International Labor Comparisons: Productivity and Unit Labor Costs in Manufacturing: Data Tables http://www.bls.gov/fls/intl_prod_tn.pdf

[18] Ibid.

[19] Ibid.

The United Kingdom, which had experienced a slight decrease in overall production between 1990 and 2010, from 94.8 to 93.3, experienced a rise in output per worker hour from 70.3 to 125.6 during that same period.[20] Chapter V of this report discusses how increased implementation of robotics and other forms of advanced manufacturing technology have improved productivity, in terms of worker output per hour, while also improving the quality of production in advanced goods. As a key point, these higher-quality goods are also specifically more often high-value goods. However, this automation comes at the cost of lower-skilled manufacturing jobs in developed countries.

Conversely, and not surprisingly, there has been a steady decline in manufacturing employment in developed countries over the past twenty years. According to the United States Bureau of Labor Statistics International Labor Comparisons, between 1990 and 2000 a general decline of manufacturing employment began in developed countries, with a decrease in employment from 21.3 million to 19.6 million in the United States, 15.0 million to 13.1 million in Japan, 8.8 million to 8.6 million in Germany, and 6.0 million to 4.4 million in the United Kingdom. By 2010 manufacturing employment declined substantially in all the developed countries. The number of manufacturing jobs fell to 14.0 million in the United States, 10.4 million in Japan, 8.1 million in Germany, and 2.9 million in the United Kingdom. As a consequence, and as an example of the political reaction, initiatives such as the White House's Advanced Manufacturing Partnership (AMP)[21] have sought to address this trend and restore domestic employment through the creation of new local, specifically advanced, manufacturing jobs. However, although the AMP is focused on advanced manufacturing, many politicians and citizens continue to overlook the importance of creating specifically sustainable employment in manufacturing, which requires that such jobs cannot be more competitively relocated elsewhere within a global production network (GPN).

The aggregate data succeed in reflecting the basic changes in the structure of global production, yet fail to illuminate the decomposition of production. When we turn to the results of complex global production networks, the aggregate data do not tell us what we need to know. What we want to know, of course, is how supply networks actually operate to produce final goods for the consumer or the industrial user. Certainly, we want to know the extent of the decomposition of production; trade across both national borders and corporate boundaries. However, the existing data on the trade of intermediate goods does not provide a clear picture of the decomposition of production. The data remain too aggregated to assess easily the patterns of trade in intermediate goods or even whether the proportion of exports in intermediary goods has increased relative to the volume of total global exports. The sectors discussion in chapter II addresses this deficiency. This makes it difficult to evaluate the shift to the geographic organization of manufacturing around phases of production. Consequently, it remains open

[20] Ibid.

[21] White House, Office of the Press Secretary, "President Obama Launches Advanced Manufacturing Partnership (AMP)" [Press Release], June 24, 2011, www.whitehouse.gov/the-press-office/2011/06/24/president-obama-launches-advanced-manufacturing-partnership/.

to debate whether trade in intermediate goods as a proportion of final goods has increased with the volume of global exports.

The challenge of data aggregation lies with the categorization of intermediate and final goods. Sturgeon et al.[22] seek to address this question through a simple recategorization of the traditional broad economic categories.[23] They combine two of the traditional broad economic categories, consumption and capital goods, into a single "final" goods category. Sturgeon et al. argue that the resulting intermediate and final goods categories and consequent analysis better reflect the de facto dichotomy between suppliers and lead firms of GPNs in which different classes of GPN actors, suppliers and lead firms, tend to trade in intermediate and final goods, respectively.[24] Moreover, this challenge is further complicated through the increasing difficulty in differentiating between production and services. The instability of the location of value in production networks is the crucial feature. This is addressed in the next two chapters.

C. The basic implications of the decomposition and recombination of production

This decomposition of manufacturing and services, the pervasive reorganization and experimentation, however described, has three implications that we wish to emphasize. First, each production element (a component, a subsystem, a module or service bundle) suddenly becomes a potential product, a point of competition with possible new competitors in interfirm and international trade.[25] For some firms, regions and countries, that may mean a loss of competitive advantage or diminished price premiums; for others, it represents an array of new opportunities: opportunities to enter new businesses, or to tweak or reformulate older offerings.

Second, if Charlie Wilson, then CEO of General Motors, was ever right in proposing that what was good for GM was good for the United States, that the interests of giant integrated companies and their home communities were closely aligned, he would certainly find it hard to make the argument now.[26] The core location of innovation, not just employment, is at issue. Often governments invest in the stimulation of R&D projects by "their" national companies in the hope that they will translate to new jobs and industries created within national borders. However, those same supposedly national firms then often locate the downstream activities, where job creation and economic growth benefits might be maximized,

[22] T. Sturgeon and O. Memedovic, "Mapping Global Value Chains: Intermediate Goods Trade and Structural Change in the World Economy," working paper, UNIDO: Development Policy and Strategic Research Branch. (May 2010).

[23] Ibid.

[24] Ibid.

[25] Breznitz (2007).

[26] Nonetheless, in a perfect example of the double bind in which states find themselves, when Detroit came calling, the Obama administration answered. It is an ironic that the once-proud GM, whose managers truly believed that the interests of the United States are best served by advancing the interests of their company, is now part-owned by the American tax payers and desperately needs not only to succeed but to explain to itself and the world what it means to be a United States conglomerate in a decomposed world.

in other places, locations that offer unique advantages that have very little to do with novel product innovation.[27] To compete, places and firms must both develop competencies and assets that allow them to retain high-value-added activities and good jobs.[28] Of course, that objective means different things for firms and places, and different things for different places.

Third, manufacturing in this era of global competition, for companies, can be either a strategic asset or a vulnerable commodity. For companies, the question is: "When can production serve to generate and maintain advantage? When is production under direct corporate control essential to creating value? Under what circumstances is the lack of in-house world-class manufacturing skills a strategic vulnerability? Conversely, when is it simpler and easier to just buy production as a commodity service?" For the country, or the region perhaps, the question becomes: "What can be done to make this country/region an attractive location for world-class manufacturing, an attractive place for companies to use production to create strategic advantage?"

D. When is production a strategic asset and when is it a commodity?

At one end are full commodities, components or products that are largely interchangeable and competing essentially on price and delivery times. In between, production knowledge can be of tremendous value because the know-how is difficult to replicate. In some cases, this manufacturing knowledge is so valuable that a firm will make critical machinery in-house or retain especially valuable segments of the production process in the home country. At the other end might be products developed with radically new materials, technologies and processes. Sectors that depend on nanotechnology-based materials are all about how you make things. Products that depend on biotechnology are also likewise about how you make things. So, in this big category of new materials-based production, the ability to know how to make things, to be a strategic leader, can be crucial in the ability to capture value or design next-generation products. Indeed, when Toyota developed the hybrid, it considered the electronics of the hybrid so crucial that it brought them back in-house from its original joint venture with Matsushita Electric.

The strategic place of production is evident if we ask who will dominate the new sectors. Will those who generate or even own, in the form of intellectual property rights, the original science-based engineering on which the nanotechnology or biotechnology rests be able to create new and innovative firms that become significant players in the market? Or will established players in pharmaceuticals and materials absorb the science and science-based engineering

[27] Breznitz(2007); D. Breznitz & A. Zehavi,"The Limits of Capital: Transcending the Public Financer-Private Producer Split in Industrial R&D Research Policy", *Research Policy* 39 (2010): 301-312.

[28] J. Zysman, N.C. Nielsen, D. Breznitz, with D. Wong, "Building on the Past, Imagining the Future: Competency-Based Growth Strategies in a Global Digital Age," working paper, BRIE, http://brie.berkeley.edu/publications/WP181.pdf.

knowledge and techniques, by purchasing firms that have spun out from a university or, alternately, by parallel internal development by employees hired from those same universities?

There is an ongoing, critical interaction among: *(a)* the emerging science-based engineering principles; *(b)* the reconceived production tasks; and *(c)* the interplay with lead users that permits product definition and debugging of early production. Arguably, that learning is more critical in the early phases of the technology cycle. Can a firm capture the learning from that interplay if it outsources significant production?

There will not be a single answer but, rather, a set of answers that are specific to particular industries. As important, the answer shifts with emerging technology and shifting sets of competitors. Importantly, these are not stable categories, and the conclusions depend on the circumstances. Consider the semiconductor industry, in which the underlying production process and materials evolve radically as transistor size shrinks. In this sector, the question of production, product innovation, value creation and market control remains entangled.[29] A generation ago, the industry was threatened when its ability to develop and source leading-edge production equipment was weakening. The capacity to retain an innovative edge in product seemed endangered. Now, the cycle has come full circle, after a generation in which design has often become separated from production, with foundries producing for pure design houses. Once again, the question is whether product position can be retained if the underlying technologies and their implementation in production systems cannot be maintained.[30]

E. Finding value in production: firm strategy and public policy

We have noted that intense global competition has generated both commoditization of production and an urgent search for new sources of value. Intense global competition has led to commoditization of product competition based principally on such basics as price and delivery time. Full commodities, components or products that are largely interchangeable, compete essentially on price and delivery time. In turn, commoditization drives a constant search by firms and locales for the "sweet spot" in competition (a momentary defensible point to capture distinctive advantage and profits). By contrast, some products embed value in new ways, for example, cranes that facilitate port management or autos that facilitate an emergency response, and products developed with radically new materials, technologies and processes.

Firm strategy: For the firm, the question is whether that interaction is more effective, in terms of the learning captured, within the firm or possible at all in

[29] M. Borrus, J. Millstein, and J. Zysman, "U.S.-Japanese Competition in the Semi-Conductor Industry," University of California at Berkeley, Institute of International Studies; M. Borrus, D. Ernst, and S. Haggard (Eds.), *International Production Networks in Asia: Rivalry or Riches?* (London: Routledge, 2000).

[30] National Research Council, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry*, ed. C.W. Wessner (Washington, D.C.: National Academies Press, 2003).

arm's-length marketplaces? As new processes or materials emerge, it is harder to find the requisite manufacturing skills as a commodity in the market, and consequently the new production skills become essential. Very often, this is achieved through learning-by-doing and can be a powerful competitive weapon. As important, firms must ask whether outsourcing will risk transferring core product/process knowledge, helping competitors develop strategically critical assets. Firms must have the capacity to judge which modules or components will be decisive in creating advantage, which must be developed in-house, and which can be safely sourced from outside. That judgment must include an estimation of which elements will evolve radically and which are likely to be commoditized and must then determine which in-house skills are needed in order to compete. In short, what is required is neither just the critical skills to produce particular artifacts or subroutines nor just the ability to create a system and reintegrate the decomposed outsourced components and constituent elements, but a combination of both.

Policy for places: production, innovation and clusters: For the country or region, the question is whether ongoing production activity is needed to sustain the knowledge required to implement the new science and science-based engineering. In other words, a regional or national government might not care whether the learning goes on in a specific firm, as long as the learning is captured in technology development within its domain. Those intimate interplays have traditionally required face-to-face, and hence local and regional, groupings.

For the country, or the region perhaps, the question becomes: "What can be done to make this country/region an attractive location for world-class manufacturing, an attractive place for companies to use production to create strategic advantage?"Core governance choices for locales, as for firms, comprise where to specialize and whether to emphasize the constituent elements of the product or focus on the system integration activity of putting the whole back together again. Just as there were multiple choices by firms and varied models of success, national successes (or failures) demonstrate that a plethora of viable regulatory regimes and strategic growth options exist.[31]

The decomposition of production and its reorganization around phases rather than sectors forces places to make decisions about where they want to specialize. As we argue in chapter IV, the basis of this discussion must be on phases of production, not sectors. Regional strategy must focus on the core competencies that underpin diverse activities, firms, and sectors that are central to the competitive advantage of companies and consequently of places as well. Developing competencies, and the regional capacity to see those competencies combined in productive and profitable activities, must be the focus of growth strategies. Strategies must ensure that investments of all sorts continuously add to the region's competencies and the capacity to combine them productively. Consider the discussion about the creative class as an example of a "competency" and an

[31] D. Rodrik, *One Economics, Many Recipes: Globalization, Institutions, and Economic Growth* (Princeton, NJ: Princeton University Press, 2007); Breznitz (2007).

investment to develop it.[32] The notion of the creative class is that, because creative and talented people are required for firms and regions to adjust and adapt in the global economy, policy should focus on attracting and promoting this talent or competency. This is the right track, but a singular focus on one competency is far too narrow. The notions of attracting a creative class, distinctive investment in digital networks and training strategies are all aimed at this problem of developing regional competencies. The problem is fundamentally "developing the inherent creative skills broadly across the education system so that we raise the creative capabilities of all, not just a few elites. The higher paying value creating jobs in the economy will be filled by folks with a significant creative component to their skill sets. The issue is the broadly based creative capacity (we use the term "competency")."[33] The regional capacity to combine and deploy these competencies in productive activity and profitable firms, supporting employment and growing real incomes, also depends on the infrastructure of communications and transportation.

Let us consider for a moment the notion of "competency" as the core requirement to compete in an intensely competitive global economy. In a world of commodities, the challenge is to find the sweet spot in the value network. The question for places is which investments to make, and how, so that firms at their particular locations can develop distinct strategies for generating specific advantages. The core idea to consider is what a place is competent at doing and how to deepen those competencies, expand the list, and ensure the local capacity to combine competencies into productive activity.

Which competencies permit a firm or a locale to occupy high-value-added segments of the value network? In chapter IV, we specify five competency domains, each essential for corporate capacities to compete globally and consequently something a "place" might want to provide. The list is not meant to be definitive, but indicative. Indeed, within each of these competency domains a wide array of "competencies" is at play, some of which are not necessarily compatible. But even if we cannot draw the boundaries clearly at this point, and might debate what falls in which category, we need to start the conversation and the mapping somewhere. These competencies are sometimes bundled inside companies and sometimes outsourced, but a region or locale wants to be the location where they take place.

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[32] R. Florida, *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life New York*: Basic Books, 2003.

[33] The framing of this concept was aided by the insights of Jonathan Murray.

II. Where is the value in the value networks?

Martin Kenney[34]

A. Introduction

International trade statistics are part of the nearly constant politicized debates in countries around the world. Remarkably, even as the collection of trade statistics has improved and been standardized, their value for understanding the beneficiaries of burgeoning global trade has been increasingly dubious. It is not just a matter of who ships what to whom but of where the value is captured. This chapter reviews the literature on the capture of value in specific products. It draws upon the most detailed micro-level case studies that take a "bottom-up" approach to examining in which country particular value chain nodes and their concomitant employment are located (note that if we accept that stockholders are the ultimate residual beneficiaries of the profits earned, the profits would have to be allocated to the countries where the stockholders reside). The data and studies reviewed conclusively indicate that different corporate functions, and the wages attached to them, are also geographically segmented. For the products that we reviewed, it is possible to generalize and conclude that the highest value-added activities are located in the developed countries, which are also, for the most part, the most important locations for end-user consumption. If end-user consumption relocates because of a growth of wealth in what are now the lower-wage manufacturing countries or there is a progressive impoverishment of the developed country markets, then the location of the higher- and even highest-value functions, such as design, may eventually relocate to these other countries. One interesting case is that, today, Tokyo is one of the world's fashion hubs, perhaps, not New York, Milan, or Paris, but an important second-tier location. Similarly, Japan is now a hub for sourcing the most advanced fabrics in the world. Another example is the Korean K-Pop music phenomenon that is now a global cultural good. None of these cases could have been predicted fifty years ago.

One of the most difficult issues in understanding the costs and benefits of the globalization of work is to understand where and by whom the value is created in what have evolved into long riverine chains that organize the provision of products and services. These knotty issues vex policymaking globally. To illustrate, United States politicians criticize China for "stealing" United States jobs, while Chinese government officials worry about the low wages of their workers, the transfer of wealth abroad through Western (read United States) control of

[34] Martin Kenney is a professor of human and community development, University of California at Davis and senior project director, Berkeley Roundtable on the International Economy; e-mail: mfkenney@ucdavis.edu.

intellectual property (patents, copyrights and trademarks), and the possibility that significant upward revaluation of the renminbi could make the country's exporters uncompetitive. To China and other developing countries, it might appear that an enormous amount of work is done on their soil, and much of the pollution is in their countries, while they are capturing very little value for the products manufactured.

Apple, in many respects, is an iconic, though exaggerated, example of the value-capture equation. In late January 2012, it announced that its sales in the fourth quarter of 2011 were US$ 17.3 billion, or 37.4 per cent of total revenue with a net income of US$ 46.3 billion.[35] Yet, even as its revenues, profits and margins exploded, the United States news media reported on the difficult labour conditions and low wages Chinese workers experience in the Taiwanese-owned Foxconn factories.[36] Although Apple, because of its fabulous profits, has been the focus of criticism over labour conditions, nearly all the electronic goods producers either used the same contractors or had factories with similar labour practices in operation in China. What these stories and myriad others confirm is that assembly workers in these value chains capture almost none of the value created, seemingly regardless of the profits of key firms in the chain.

One important and glaring exception to this argument is that manufacturing has become more globally dispersed, a testament to China's role in attracting manufacturing of all sorts. As a broad generalization, "continental" reorganizations are taking place in the location of manufacturing—such as the role of Mexico in supplying the United States, Eastern Europe, Turkey, and, to a lesser degree, North Africa in supplying Western Europe. However, these reorganizations are superseded by the role of China in supplying the world. Even as it competes with the lower-wage countries for export partners, China is also gaining market share in these lower-wage countries by competing with the local firms supplying domestic markets. So, for example, Mexicans who worship at the shrine of Our Lady of Guadalupe in Mexico can buy trinkets depicting the Virgin Mary that are made in China.

Karl Marx believed that capitalism would spread and eventually become a global system tying together countries and workers. Today, more than ever, this appears to be the case, and, more important, the production process and related division of labour are far more widely distributed across national boundaries. Although many have focused on the increasing ease with which data crosses geographic and national boundaries, objects with weight and mass have also become more mobile. Despite great interest in where the value of a commodity (the thing sold in the market) is added and captured, far less detailed analysis has been conducted than one might expect. This section reviews the existing state of knowledge in an effort to better understand what we already know.

[35] Apple Quarterly Report (2012).

[36] See, for example, C. Duhigg and D. Barboza, "In China, Human Costs Are Built into an iPad," *New York Times*, January 25, 2012, www.nytimes.com/2012/01/26/business/ieconomy-apples-ipad-and-the-human-costs-for-workers-in-china.html?_r=2/ (accessed January 25, 2012).

Apocryphal Barbie example

In 1996, the *Los Angeles Times* published an article that discussed a made-in-China Barbie doll sold at a local store in an attempt to understand where the components of the total price of the doll were captured.[37] Initially, assembly had been done in other parts of Asia and her production was first offshored to Japan. But by 1996 Barbie was assembled in China. Value capture for Barbie as a commodity was even more complicated. The retail price of the Barbie doll was US$ 10, of which the reporter calculated that US$ 7 was added in the United States from the costs of transportation, marketing, and wholesale and retail markups, and Mattel's profit of approximately US$ 1. The remaining US$ 2 were the costs of production, which were spread throughout Asia. But even this did not capture the entire story, as the feedstock for Barbie's plastic came from the Middle East and then the plastic body was injection molded in China. At the time this article was published, the nylon hair was imported by China from Japan, rather than less expensive Italy, because the quality of Japanese nylon hair was superior. No data is available to confirm whether this pattern continues.

One of the difficulties in this analysis is that we are not sure of the origin or of which firm bears the cost of the capital equipment used in the Chinese factories. In some sectors equipment and facility costs, that is, capital investment, are an important component of overall costs. For example, if the plastic injection molding machines (or the molds) for Barbie were provided by Mattel, then part of its overall "profits" may in fact be factory and equipment depreciation. In doll production, this is probably a minimal cost, but for other products, such as semiconductors or automobiles, capital investment can be enormous. At the time this news article was written, the capital equipment was imported from developed countries, most likely Japan. It is also possible that, at that time, the molds for the body were made in either the United States or an Asian developed country such as Japan. It is possible that, given the relative lack of sophistication of the Barbie doll, today nearly everything, including the capital equipment, molds, hair, and paints, is produced in China. However, the nozzles for extruding the nylon might still be produced in Japan. Only the role of Mattel's headquarters in the Los Angeles area remains the same and is able to capture relatively similar shares of the entire value created, though its margins might be squeezed by the giant retailers, such as Toys-R-Us and Wal-Mart.

B. Electronics

Electronics is where much of the most detailed research on value capture has been undertaken. It is also interesting because scholars such as Breznitz[38] and Rodrik[39] have pointed out that there is the enormous potential for national and

[37] R. Tempest, "Barbie and the World Economy," *Los Angeles Times* (September 22, 1996), http://articles.latimes.com/1996-09-22/news/mn-46610_1_hong-kong/4 (accessed January 27, 2012).

[38] D. Breznitz, *Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan, and Ireland* (New Haven: Yale University Press, 2007).

[39] D. Rodrik, "What's So Special About China's Exports?" *China & World Economy* 5 (2006): 1-19.

firm upgrading, as the cases of firms such as Samsung, HTC, Acer, Lenovo and Huawei have shown. The ability of countries and firms to use electronics for upgrading their industrial activities and presumably capturing more value is what makes electronics so interesting and the following case studies so relevant.

B.1 Notebook computers

The personal computer industry (with the notable exception of Apple) is dominated by two firms, Microsoft and Intel, or what Zysman and Borrus broadly referred to as Wintel.[40] Since IBM's control over the BIOS was broken by Cirrus Logic and Compaq, PC assemblers have been involved in a commodity business and have, for all intents and purposes, been unable to differentiate themselves on any basis except price.[41] The only significant exception to this has been intermittently in notebook computers, in which size, weight and quality have, for short periods, provided some succour against the constant downward pressure on price. Even firms such as Dell that, at times, appeared to have market power and assembled PCs in the United States and other locations closer to the end-user market, have responded to price competition by moving assembly to China.[42]

The geography of value chains evolves over time, and the shortcoming of many studies' analyses is that they do not depict the dynamics of value-chain geography. For notebook computers, Dedrick and Kraemer show that location of various nodes in the value chain has been changing (see figure I).[43] However, they contrast the change only from 2003 to 2006, when, in the early days of the notebook computer, most segments of the value chain were located in Japan and Japanese firms, and, although IBM's ThinkPad was designed in the United States, IBM Japan had a significant manufacturing role. Gradually, firms based in Taiwan Province of China that had built significant expertise in assembling desktop computers entered the business at the low-end of the notebook market as subcontractors for United States brands and gradually eroded the Japanese manufacturing advantages. Even as the Taiwanese firms captured an increasing number of the segments of the value chain, they had to respond to increased competition by offshoring manufacturing (assembly) to China. For commodity desktop and notebook computers, Dedrick and Kraemer found that "Dell and HP both operat[ing] design centres in Taipei with hundreds of engineers suggests that even more jobs can potentially move offshore."[44] The tendency to transfer different segments of the notebook PC value chain to Asia is likely to continue.

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[40] M. Borrus and J. Zysman, "Globalization with Borders: The Rise of Wintelism as the Future of Industrial Competition," *Industry and Innovation* 4, No. 2 (1997).

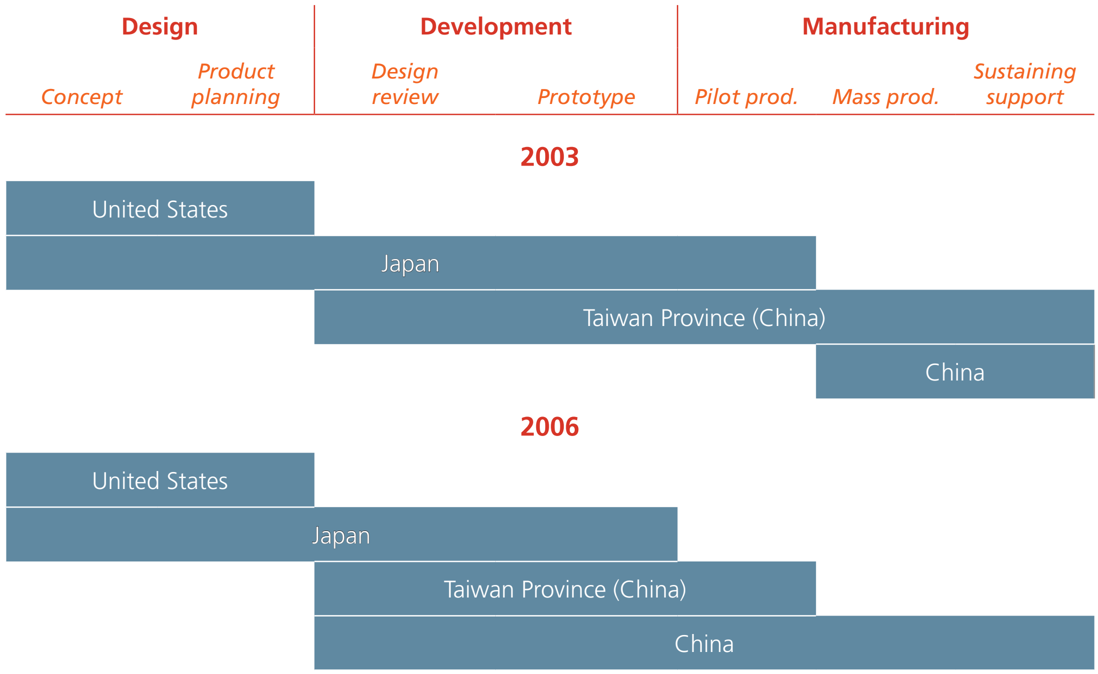
[41] See, for example, R.N. Langlois and P.L. Robertson, *Firms, Markets, and Economic Change: A Dynamic Theory of Business Institutions* (London: Routledge, 1995).

[42] For an analysis in the 1990s, see J. Curry and M. Kenney, "Beating the Clock: Corporate Responses to Rapid Change in the PC Industry," *California Management Review* (Fall 1999): 8-36.

[43] J. Dedrick and K.L. Kraemer, "Is Production Pulling Knowledge Work to China? A Study of the Notebook PC," *IEEE Computer* 39, No. 7 (2006): 36-42.

[44] Ibid.

Figure I. The location of various activities in developing and producing a new notebook computer



Source: J. Dedrick and K.L. Kraemer, "Is Production Pulling Knowledge Work to China? A Study of the Notebook PC," *IEEE Computer* 39, No. 7 (2006): 41.

The tendency for PC assembly to be relocated to Asia is well known. This is facilitated by the fact that most notebook PCs are comparatively simple assembled products. Much of the value is in the components, so their composition must be examined to understand how the value in the entire product is distributed globally. For example, Jason Dedrick et al. compared the value of the inputs in a Chinese-assembled iPod and a Hewlett Packard notebook computer (see table 1).[45] The top-of-the-line notebook at that time had a factory cost of US$ 2,196. The breakdown of its input value is interesting and revealing. The highest value was in the Intel processor, nearly all of which are fabricated in the United States. The display, storage (hard disk) and software are produced by firms in developed countries, with the exception that many displays are produced by Samsung in the Republic of Korea. The battery and memory are also produced by either Korean or Japanese firms. The assembly, enclosure, input devices (keyboard and mouse), printed circuit boards, and hundreds of other components (some of which might also be produced in developed countries or by firms domiciled in developed countries) account for only 23 per cent of the total value of the components in the notebook computer.

[45] J. Dedrick, K.L. Kraemer and G. Linden, "Who Profits from Innovation in Global Value Chains? A Study of the iPod and Notebook PCs," *Industrial and Corporate Change* 19, No. 1 (2009): 81-116.

Table 1. Comparison of inputs as a percentage of factory cost: 30 GB Video iPod and HP nc6230 notebook

Component	*Video iPod (in percentage)*	*nc6230 Notebook (in percentage)*
Software	NA	12
Storage	51	13
Display	16	16
Processors	9	27
Assembly	3	3
Battery	2	5
Memory	4	4
PCBs	2	3
Enclosure	2	1
Input device	1	2
Subtotal for key components	90	86
Hundreds of other components	10	14
TOTAL	**100**	**100**
TOTAL PARTS	**451**	**2,196**

Source: J. Dedrick, K.L. Kraemer and G. Linden, "Who Profits from Innovation in Global Value Chains? A Study of the iPod and Notebook PCs," *Industrial and Corporate Change* 19, No. 1 (2009): 7.

The profitability of the components included in the HP notebook computer differs dramatically (see table 2). The highest profits are captured by Microsoft and Intel, though a number of United States, Japanese and Korean firms capture significant profits and profit margins. The unknown assembler has the worst returns and very low profit margins. Within the value chains of most of the suppliers, there is an assembly component, for example, chip assembly and testing, which is relatively low value-added. The PC value chain is particularly interesting because the brand name assembler does not have particularly high profit margins as 38 per cent of costs in the PC inputs are due to Microsoft's and Intel's inputs. Most important, the operating system and processor chip set face little competition. They are close to being monopolies and can capture outsize returns.

Table 2. Profit margins of firms in the HP nc6230 supply chain, 2005

Function	*Supplier*	*Gross margins (percentage)*	*Operating margins (percentage)*	*Return on assets (percentage)*
Operating system	Microsoft	84.8	36.6	17.2
Processor plus logic, wireless chips	Intel	59.4	31.1	17.9
Videomemory	HynixSemiconductor	37.3	24.9	17.7

Function	Supplier	Gross margins (percentage)	Operating margins (percentage)	Return on assets (percentage)
Card bus and battery charge controllers	Texas Instruments	48.8	20.8	15.4
Ethernet controller	Broadcom	52.5	10.9	9.8
Memory board	Samsung	31.5	9.4	10.3
Retailer	Best Buy	25.0	5.3	9.6
I/O controller	Standard Microsystems	46.0	4.2	2.7
DVD-ROM	Matsushita	30.8	4.2	1.9
Battery pack	Unknown	24.0	4.0	2.4
Lead firm	HP	23.4	4.0	3.1
Display assembly	Toshiba Matsushita	28.2	3.9	1.8
Hard drive	Fujitsu	26.5	3.8	1.8
Assembly	Unknown	6.1	2.4	4.6
Distributor	Unknown	7.7	1.5	1.9
Graphics processor	ATI Technologies	27.6	1.1	1.0

Source: J. Dedrick, K.L. Kraemer and G. Linden, "Who Profits from Innovation in Global Value Chains? A Study of the iPod and Notebook PCs," *Industrial and Corporate Change* 19, No. 1 (2009): 12.

B.2. Nokia mobile phones[46]

The Nokia N95 Smartphone was introduced in September 2006 and at that time was a top-of-the-line phone. The Finnish research organization ETLA performed a value chain analysis on the N95 to understand where the value embodied in the phone was created and captured. Only such detailed studies, and there are not many, can really answer the question of the location of value creation. The complicated nature of understanding who captures the value is illustrated by the fact that the "N95's main processor was provided by Texas Instruments (United States). The hardware design was made in Dallas (United States) and in Nice (France). Much of the software design and its integration to hardware were of Indian origin. Besides Dallas (United States), the processor was also manufactured in Japan."[47]

In the N95 case, as with many information technology devices, intellectual property can be an important portion of the overall value. Ali-Yrrko et al. explicitly note that Nokia has significant intellectual property, which it cross-licenses with competitor firms. If a new entrant without an IP had to acquire licences, they estimate that instead of the approximately 20 euros (which is more than 10 per cent of the entire cost of materials) Nokia must pay for licences, the cost would be approximately 40 euros or nearly 20 per cent of the cost of materials (excluding final assembly)—a substantial competitive handicap. This "tax" for

[46] This section summarizes the work of J. Ali-Yrkkö, P. Rouvinen, T. Seppälä and P. Ylä-Anttila, "Who Captures Value in Global Supply Chains? The Case of Nokia's N95 Smartphone," ETLA Discussion Paper 1240, February 28, 2011, http://www.etla.fi/files/2592_no_1240.pdf (accessed January 28, 2012).

[47] Ibid., 4ff.

intellectual property should be a substantial barrier to new entrants—which presumably would be from developing countries.

The final assembly/manufacturing cost of the N95 was estimated at 11.5 euros, that is, 2 per cent of the pre-tax final sales price.[48] This is less than the cost of licensing, thus the assembly location is not a significant indicator of where and by whom the value is captured. The N95 was assembled in only two locations, Finland and Beijing, China, and in both locations was assembled only in Nokia factories. According to Ali-Yrrko et al.'s calculations, Nokia added approximately 50 per cent of the total value-added. In terms of the geography of where the value-added is captured, their analysis is particularly interesting because it uses different assumptions about how to attribute the value added. Obviously, if there had been no production in Finland and it had all been in China, then their column B (see table 3) would have been somewhat different, with Asia having a higher percentage.

Table 3. The value-added breakdown of Nokia N95 by major region (in percentage)

Location	*Head-quarters*	*Location of production factors*	*10% to HQ country and 90% to production country*	*Location of production corrected for productivity*	*Columns 4 and 5 combined*
Finland	47.2	34.0	35.3	37.9	38.8
Other EU-27	1.9	9.9	8.6	7.7	7.1
North America	6.6	9.1	8.9	9.1	8.9
Asia	4.7	8.3	8.0	6.6	6.4
Other countries	1.3	0.8	0.9	0.3	0.4
Unaccounted inputs	3.1	3.1	3.1	3.1	3.1
Vendor of vendors	18.7	18.7	18.7	18.7	18.7
Nation of final sales	14.5	14.5	14.5	14.5	14.5
Nation of final assembly (Finland or China)	2.1	2.1	2.1	2.1	2.1
Total	**100**	**100**	**100**	**100**	**100**

Source: J. Ali-Yrkkö, P. Rouvinen, T. Seppälä and P. Ylä-Anttila, "Who Captures Value in Global Supply Chains? The Case of Nokia's N95 Smartphone," ETLA Discussion Paper 1240, February 28, 2011, www.etla.fi/files/2592_no_1240.pdf (accessed January 28, 2012), p. 11.

The N95 study went further than most articles and considered the differences in how these results would be reported in international trade statistics (see

[48] Ibid., 9.

tables 4 and 5), which show that an N95 exported from Finland to Germany would have different impacts on Finland depending on from which country the N95 was exported and to which country it was sent. However, the most interesting case is one in which Nokia exports a phone from China to the United States. In this case, it appears as a Chinese export, when in fact it is Nokia that is undertaking the export. Despite the changing destination, the true value-added in Asia increases only slightly from 13 per cent to 16 per cent of the total (and some of that value-added comprises sophisticated parts, such as Samsung DRAM produced in the Republic of Korea and a camera probably produced in Japan).

Table 4. N95's geography of gross value in two cases as recorded in international goods trade statistics (in euros)

	Exports from Finland to Germany	*Exports from China to the United States*
Assembly in Finland with final sale in Germany	467	
Assembly in China with final sale in United States		467

Source: Ali-Yrkkö et al. (2011: 12).

Table 5. The N95's gross value in terms of the geography of value added (in percentage)

Locations	*Finland*	*Other EU-27*	*Asia*	*North America*	*Rest of world*
Assembly in Finland, final sale in Germany	41	27	13	14	5
Assembly in China, final sale in the United States	39	12	16	28	5
Average of all combinations	38	16	18	17	11

Source: Ali-Yrkkö et al. (2011: 12).

What is most interesting is Ali-Yrrko et al.'s conclusion, namely, that they expected that at a minimum Nokia's Beijing plant should have received "roughly 0.8 billion of service exports from Finland to China in 2007."[49] However, when examining the data Statistics Finland reported, they found that "the total services [exports] across all industries from Finland to China were 0.6 billion in 2007. Thus, the recorded figure did not even account for one phone model, which in 2007 accounted for less than 1.5 per cent of all sold Nokia phones and less than 7.5 per cent of all Nokia phone sales (not to mention service exports of all other actors and industries)."[50]

[49] Ibid., 13.

[50] Ibid.

In another study of four cell phone suppliers (not the brand firm), Dedrick et al.[51] found that the gross profit shares differed by manufacturer, but, at the time of their study, for many of the firms the capture of profits by suppliers was geographically dispersed in the developed countries (see table 6). Most remarkable was the relatively low percentage of gross profit captured by Asia other than Japan. It is likely that this is changing, not because China is capturing greater profits but because Korean firms, in particular Samsung, are becoming more important in the supply chain. In mobile phones, Dedrick et al. suggest that "job creation in terms of headcount may be skewed towards the location where the labour-intensive assembly is located, while the home nation may receive the higher value-added jobs in R&D, marketing, and management."[52] In the case of Nokia, which has assembly in Finland, the case is likely to be similar.

Table 6. Estimated gross profit shares for four phones, 2010 (in percentage)

Supplier/product	*United States*	*Japan*	*Other Asia*	*Europe*	*Unidentified*	*Total*
Motorola Razr	36	28	6	0	30	100
Palm Treo 650	39	19	8	3	31	100
RIM Blackberry Curve 8300	41	2	8	12	37	100
Nokia 7710	17	35	2	11	36	100

Source: Dedrick et al. (2011: 510).

B.3. Apple—iPad, iPhone, and iPod

To continue the Apple example, the iconic electronics products of the past six years are Apple's mobility product family (the "i"s). This series of products has made Apple one of the most profitable electronic consumer product makers in history. Apple has no production facilities and relies entirely on subcontractors, Taiwanese firms that have production facilities in China. All the research examining value-added suggests that the Taiwanese assembler had profit margins lower than any except those of the distributor. Interestingly, the gross margins for the controller, video and primary memory chips were larger than those of Apple, though, with the exception of Portal Player, the return on assets was extremely high (see table 7).

[51] J. Dedrick, K.L. Kraemer, & G. Linden, "The Distribution of Value in the Mobile Phone Supply Chain," *Telecommunications Policy* 35, No. 6 (2011): 505-52.

[52] Ibid., 506.

Table 7. Profit margins of primary firms in the Video iPod supply chain, 2005 (in percentage)

Function	*Supplier*	*Gross Margin*	*Operating margin*	*Return on assets*
Controller chip	PortalPlayer	44.8	20.4	19.1
Lead firm	Apple	29.0	11.8	16.6
Video chip	Broadcom	52.5	10.9	9.8
Primarymemory	Samsung	31.5	9.4	10.3
Battery	TDK	26.3	7.6	4.8
Retailer	Best Buy	25	5.3	9.6
Display	Toshiba/Matsushita	28.2	3.9	1.8
Hard drive	Toshiba	26.5	3.8	1.7
Assembly	Inventec	8.5	3.1	8.1
Distribution	Ingram Micro	5.5	1.3	3.1
Minormemory	Elpida	17.6	0.1	–1.0
Minormemory	Spansion	9.6	–14.2	–9.2

Source: Dedrick et al. (2009: 92).

When Kraemer et al.[53] extended their iPod study, they found that for every iPhone (see table 8) and iPad imported to the United States (see table 9), the trade deficit increased about US$ 229 and US$ 275, respectively. This earlier result is confirmed by their prior finding that "for every US$ 299 iPod sold in the United States, the United States trade deficit with China increased by about US$ 150."[54] As was the case with iPod, "the value captured from these products through assembly in China is around US$ 10."[55] What is remarkable, in particular for the iPhone, is the enormous profit margins for Apple. The iPad had a higher cost of materials and concomitantly lower profit margins. However, in each of these cases, the Chinese labour costs are only about 2 per cent of the entire value.

Table 8. Distribution of value for the iPhone, 2010 (in percentage)

Costs and profits	*Percentage of total value*
Apple profits	58.5
Korean profits	4.7
Unidentified profits	5.3
Japan profits	0.5
Taiwan Province profits	0.5
EU profits	1.1
Non-Apple U.S. profits	2.4

[53] K.L. Kraemer, G. Linden and J. Dedrick, "Capturing Value in Global Networks: Apple's iPad and iPhone," CRITO Working Paper, July 2011, http://pcic.merage.uci.edu/papers/2011/Value_iPad_iPhone.pdf (accessed February 1, 2012).

[54] Ibid., 7.

[55] Ibid.

Costs and profits	Percentage of total value
Cost of inputs: China labour	1.8
Cost of inputs: materials	21.9
Cost of inputs: non-China labour	3.5

Source: K.L. Kraemer, G. Linden and J. Dedrick, "Capturing Value in Global Networks: Apple's iPad and iPhone," CRITO Working Paper, July 2011, http://pcic.merage.uci.edu/papers/2011/Value_iPad_iPhone.pdf (accessed February 1, 2012), p. 5.

Table 9. Distribution of value for the iPad, 2010 (in percentage)

Costs and profits	Per cent of total value
Apple profits	30
Korean profits	7
Unidentified profits	5
Japan profits	1
Taiwan Province profits	2
Non-Apple U.S. profits	2
Cost of inputs: China labour	2
Cost of inputs: materials	31
Cost of inputs: non-China labour	5
Distribution and retail	15

Source: Kraemer et al. (2011: 5).

Apple does not produce components or assemble products, but rather sources components and contracts assembly. As we have already seen, the value-added from assembly is insignificant. Despite this obstacle, the information and communication industries offer many opportunities for upgrading, as countries such as China can begin designing and fabricating semiconductors (in the case of semiconductor fabrication, Shanghai Manufacturing Industrial Corporation is the most salient example). Below we examine the disk drive industry in greater detail, but for the Apple products and notebook computers, flat panel displays (FPDs) and semiconductors are a significant portion of the cost of goods. In the case of FPDs, the only significant producers are the Republic of Korea and Taiwan Province, as recently Japan has been retreating from large displays. According to a recent news report, the Republic of Korea and Taiwan Province together have a global market share of about 90 per cent, and Japanese firms such as Sharp are adjusting to this by licensing technology and selling older equipment to Chinese producers.[56]

[56] D. Wakabayashi, "First GDP, Now Panels: China Outstrips Japan Again," *Japan Real Time* (June 14, 2011), http://blogs.wsj.com/digits/2011/06/14/first-gdp-now-panels-china-outstrips-japan-again/ (accessed January 31, 2012).

B.4. Semiconductors

In semiconductors, China became the largest global consumer by far in 2009 (see table 10), consuming 41 per cent of all semiconductors, up from 23 per cent in 2003.[57] In effect, this enormous market provides ample space for China's semiconductor production to increase, and this offers opportunities to increase domestic production. In some cases, the increase will come through foreign firms establishing production facilities in China. For example, the value of Intel's Chinese production increased to US$ 2.3 billion in 2009 after it built a fabrication facility, which is the most capital- and engineering-intensive manufacturing activity in the semiconductor value chain.[58] China is rapidly upgrading its semiconductor fabrication skills, which almost certainly will give it a significant presence in this, one of the highest value-added production activities.

Table 10. Worldwide semiconductor market by region, 2003-2009

	Total (in US$ billions)	*China (%)*	*Americas (%)*	*Japan (%)*	*Europe (%)*	*Rest of world (%)*
2009	226.3	41	17	16.9	13.2	11.9
2008	248.6	38.3	15.2	19.5	15.4	11.6
2007	256.3	34.8	16.6	19.1	16	13.5
2006	247.7	28.9	18.1	18.4	16.1	18.5
2005	227.5	24.8	17.9	19.4	17.3	20.6
2004	213	21.5	18.3	21.5	18.5	21.3
2003	166.4	23.4	19.4	23.4	19.4	19.3

Source: PWC, Global Reach: China's Impact on the Semiconductor Industry 2010 Update (November 2010), www.pwc.com/gx/en/technology/assets/china-semicon-2010.pdf (accessed January 30, 2012), 9.

Even though China might be rapidly increasing its semiconductor production capabilities and some low-end semiconductor design is being relocated, having tremendous manufacturing prowess will not guarantee the relocation of high-end design. For example, as Brown and Linden[59] conclude, even Taiwan Province, which probably has the largest semiconductor design industry outside the United States, largely designs semiconductors for the products in which it specializes but through its world-leading semiconductor foundries it produces chips and sophisticated products that are designed abroad. Thus semiconductor design might be more closely linked with the headquarters and overall R&D strategy, and because these semiconductors are so crucial to a firm's competitive advantage, they might be reluctant to share them.

[57] PWC *Global Reach: China's Impact on the Semiconductor Industry 2010 Update* (November 2010), www.pwc.com/gx/en/technology/assets/china-semicon-2010.pdf (accessed January 30, 2012), 9.

[58] Ibid., 31.

[59] C. Brown and G. Linden, *Chips and Change: How Crisis Reshapes the Semiconductor Industry* (Cambridge: MIT Press, 2009).

B.5. Hard disk drives

Hard disk drives (HDDs) are important storage devices for digital information. The most recent published materials concerning HDDs are for 2000. In one of these studies, Gourevitch et al.[60] show that while the United States, Japan and Europe have 28.5 per cent 0.9 per cent and 2.9 per cent of total employment in the industry respectively, they received 70.5 per cent in terms of wages. At the same time, South-East Asia provided 55.3 per cent of the employment for 19 per cent of the wages. Remarkably, though essentially all HDDs in 2000 were manufactured in Asia, the United States still captured 62.4 per cent of the wages paid in the industry. Since this paper was written, the HDD industry has undergone remarkable changes. A number of Japanese (Hitachi) and Korean (Samsung) competitors have sold their HDD divisions to United States manufacturers, and their European assembly facilities have largely been closed. Although South-East Asia, in particular Thailand, remains an important production centre, Singapore, Malaysia and the Philippines are declining as producers. China's importance is growing, though it has a trade deficit in HDDs due to a large volume of imports related to their centrality in computer assembly.[61] Despite the geographic relocation of the manufacturing centres of the HDD industry, the ownership, not only of the assemblers but also the preponderance of the parts suppliers, remains firmly in the hands of United States and Japanese firms. Given the relatively high value, low weight and extreme price competition in HDDs, there is no reason to believe that production will be relocated back to developed countries. It is difficult to determine whether large portions of the higher value-added work is being relocated to developing countries.

B.6. Electronics redux

The electronics sector is fascinating because of its complexity, which means that many variables are constantly shifting. The first observation is that innovation (technical and organizational) and branding continue to be vitally important. As noted in section B.3, Apple has created a series of hit products, the production of which is outsourced to China. However, key component makers in Japan and, more recently, the Republic of Korea, capture value because of the quality of their products and their ability to produce technically cutting-edge components. Despite the ability of Chinese and Korean firms to secure production nodes in the value network, it is Apple that captures the most for its value chain. In semiconductors and hard disk drives, there is evidence that, although China consumes these both for the domestic and global market, the highest value added continues to be captured abroad. For many electronic products, key components continue to be either made or designed in developed countries using well-compensated staff. Will this continue to be the case in the future, or will these

[60] P. Gourevitch, R. Bohn and D. McKendrick, "Globalization of Production: Insights from the Hard Disk Drive Industry," *World Development* 28, No. 2 (2000): 301-317.

[61] T. Pruangchana and W. Waressara, "Thailand's Hard Disk Drive Industry Competitiveness Analysis," in Proceedings of International Conference on Business and Economics Research, 2010, www.internationalconference.com.my/proceeding/icber2010_proceeding/PAPER_130_ThailandHardDisk.pdf Accessed May 21, 2012.

components be drawn into a vortex of cost minimization and commodification? Especially for firms that manufacture inputs, this is a constant threat. For countries, the fear is that Chinese upgrading will overtake them or drive them into ever smaller high-end niches, as occurred with the Japanese notebook computer, FPD, and semiconductor makers that retreated before Taiwanese and Korean competition. However, at this time, United States firms such as Apple for the "i" products and Microsoft, Intel, and, to a lesser degree, the PC giants Dell and HP have been able to capture the highest value in their chains. This is also true for numerous key, technically advanced, component makers. Here again, the trade statistics appear to obscure the location of value capture.

C. Automobiles

Although much has been written about automobile global value chains,[62] there has been far less research, in terms of analysis, of the value-added for various components. This is due in part to the complicated nature of an automobile, which has between 30,000 and 40,000 discrete components. Because automobiles are a heavy, bulky item and because trade in automobiles is politically sensitive because of its employment implications, the politics can be extremely complicated as well. Having said this, a shift has taken place in the percentage of total global automobile production in developing countries, though in large measure this has been driven by two phenomena: First, the rapid expansion of markets in countries such as China, Brazil and India; second, the formation of regional free trade agreements allowing free trade in automobiles and auto parts.[63]

The key exception to this generalization is the rapid expansion of automobile and motorcycle intermediate parts exportation by China, which rose from twenty-first in 1993 to fourth highest automotive parts exporter in 2008, which also made it the largest non-developed country automotive parts exporter.[64] The rise of China as an exporter of automobile parts can also be seen in United States trade statistics. For example, Klier and Rubenstein[65] found that China had captured 10 per cent of total United States parts imports in 2008, and its expansion appears to be continuing. According to the United States International Trade Administration,[66] auto part imports from China increased 35 per cent from 2009 to 2010, to US$ 10 billion.

[62] J. Humphrey and O. Memedovic, "The Global Automotive Industry Value Chain: What Prospects for Upgrading by Developing Countries," Report to Strategic Research and Economics Branch, UNIDO, 2003.

[63] T.J. Sturgeon and J.V. Biesebroeck, "Global Value Chains in the Automotive Industry: An Enhanced Role for Developing Countries?" *International Journal of Technological Learning, Innovation and Development* 4, Nos. 1/2/3 (2011): 181-205.

[64] Ibid., 190.

[65] T.H. Klier and J.M. Rubenstein, "Imports of Intermediate Parts in the Auto Industry—A Case Study," paper presented at the "Measurement Issues Arising from the Growth of Globalization" conference, Washington, D.C., November 6-7, 2009, 221, http://www.napawash.org/wp-content/uploads/2010/09/CONFERENCE-PAPERS-August-2010.pdf#page=229 (accessed January 30, 2012).

[66] U.S. International Trade Administration, Office of Transportation and Machinery, "On the Road: U.S. Automotive Parts Industry Annual Assessment," 2011, http://trade.gov/static/2011Parts.pdf (accessed January 31, 2012).

In their case study of aluminum wheel production for automobiles, they found that China was rapidly overtaking Mexico as the largest global source. According to Klier and Rubenstein, "about half of the 12 million aluminum wheels imported by the United States from China in 2008 represent OEM wheels. In the same year, Mexico exported just under 4 million aluminum wheels to the United States"[67] Other bulkier items such as seats might not be as amenable to sourcing from China, but it is rapidly becoming a source for these parts. The momentum of Chinese automotive parts export growth affects not only the United States. For example, the Deccan Herald, a south Indian[68] newspaper, reported that a recent study conducted by the Federation of Indian Commerce and Industry concluded that "imports of auto parts from China have been increasing at an alarming rate of 88 per cent per annum and with this growth rate share of China in our domestic auto component market would increase from current 2.7 to 15.6 per cent by 2012-13."[69] The article continued, stating that the research firm A. T. Kearney found that the 12,000-odd auto parts companies in China are far more competitive than the 5,000-plus firms in India for several reasons, including the lower cost of wages, steel, power, tariffs and taxes. Although many developing countries, including India and Brazil, are increasing their exports of car parts, the total value pales in comparison to exports from China. For example, the United States International Trade Administration[70] calculated that Chinese auto parts exports increased from US$ 16.7 billion in 2005 to US$ 31 billion in 2009, and they expected them to continue to increase.

Chinese auto firms have not yet exported significant numbers of assembled automobiles to the United States or Europe, but at present, for many of the parts suppliers, though not all of them, the value capture for the Chinese firms is likely to be in inexpensive labour and possibly other aspects, such as very low costs of capital, lax enforcement of environmental regulations, and lower costs for at least some inputs. The success of the Korean automakers—specifically Hyundai—shows that this could and will probably change over time.

In the successful parts of the auto industry, that is, the German and Japanese makers, the design, technical development, and management are largely retained in the home country, though branch activities mostly related to localization now occur in all the major markets, and China, in particular, is the beneficiary of upgrading. The Germans and particularly the Japanese have been careful about limiting technology and know-how transfer to developing countries.

D. Apparel

The garment business was one of the earliest industries to be offshored and probably has the widest global dispersal of production. Value capture in this

[67] Klier and Rubenstein (2009): 225.

[68] South India is the centre of the Indian auto parts industry, especially those firms aiming to export.

[69] A.J. Das, "Imported Trouble for Auto Parts Makers," *Deccan Herald* (January 31, 2012).

[70] U.S. International Trade Administration (2011).

chain is not easy to discern for a number of reasons, one of which relates to branding. Interestingly, the two largest global apparel exporters, China and the European Union (EU-15)[71] have rather different roles in the global economy. Although it is difficult in a short section to fully analyse the global division of labour in apparel, table 11 shows that the two top apparel exporters are China and the EU-15. The Chinese story is one of moving from strength to strength, and in 2009 China supplied 42 per cent of total global exports; the European story is, in many respects, more interesting because it has continued to increase exports in the face of competition from developing countries (particularly China). As table 12 shows, however, the European market is also experiencing a dramatic increase in imports from China.[72] In the meantime, other countries, such as Bangladesh, have a variety of trajectories with dramatic increases, China and Europe are the most dynamic and significant exporters, and the Republic of Korea and Mexico have experienced the greatest decreases in exports.

Table 11. Top five global apparel exporters by year, by volume and share

	1995	2000	2005	2009	1995 (% of total)	2000 (% of total)	2005 (% of total)	2009 (% of total)
World	152,532	193,728	268,416	296,901				
China	32,868	48,017	89,829	122,389	21.5	24.8	33.5	41.2
EU-15	37,857	33,984	47,757	51,614	24.8	17.5	17.8	17.4
Extra EU-15	12,006	11,486	14,405	15,436	7.9	5.9	5.4	5.2
Bangladesh	2,544	4,862	8,026	14,185	1.7	2.5	3.0	4.8
Turkey	5,261	6,710	12,922	13,079	3.4	3.5	4.8	4.4

Source: K. Fernandez-Stark, S. Frederick and G. Gereffi, "The Apparel Global Value Chain: Economic Upgrading and Workforce Development," Center on Globalization, Governance & Competitiveness. (2011): p.10.

The role of China in the global apparel chain is also remarkable, not only because of the breadth of the sectors in which it is involved but also how it is rapidly diversifying the markets to which it exports. As table 12 indicates, even as the total volume of exports from China has increased rapidly and exports to each region have increased, its export share in the Japanese and United States markets has decreased (even though volume has increased rapidly). The importance of the EU in China's total market share is also remarkable.

[71] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom

[72] G. Gereffi & S. Frederick, "The Global Apparel Value Chain, Trade and the Crisis, "Challenges and Opportunities for Developing Countries," World Bank Policy Research Working Paper 5281 (April 2010), 15, www.ds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2010/04/27/000158349_ 20100427111841/Rendered/PDF/WPS5281.pdf (accessed February 2, 2012).

Table 12. China's top five export markets for apparel, by value and share

	1992	1995	2000	2009	1992 (%)	1995 (%)	2000 (%)	2009 (%)
China (total)	32,868	48,017	89,829	122,389				
EU-15	2,954	4,462	7,444	39,728	20.8	13.6	15.5	32.5
United States	4,744	4,913	6,514	25,367	33.5	14.9	13.6	20.7
Japan	4,685	t	14,195	20,262	33.0	31.4	29.6	16.6
Hong Kong	N/A	10,301	13,875	13,102	N/A	31.3	28.9	10.7
Canada	389	366	703	3,595	2.7	1.1	1.5	2.9

Source: Frederick and Gereffi (2011: 78)

In view of the wide variety of apparel products with different market characteristics, making any generalizations about value capture by firms and countries is extremely difficult. One area that has been mentioned and that probably has the highest percentage of value capture is branded, higher fashion products. At the extremely high-end, it is likely that, as is the case with fashion shoes, described below, such apparel will continue to be produced in developing countries. However, branded fashion products are being produced internationally. For example, table 13 parses the value addition of a pair of jeans produced in China for export by a French fashion house. The jeans will be sold in France for 50 euros. The costs accumulated in China are approximately 3.2 euros. The margin captured by the French fashion house is approximately 6 euros. However, 31 euros of the final costs are in distribution, marketing, and advertising—all of which in this case would be captured in France. Interestingly if the jeans were sold outside France, if the margin remained the same, the distribution of costs would be quite different, with France capturing less in the overall gains.

Table 13. Distribution of value-added for jeans produced by French apparel producers in China and sold in Western Europe (in euros)

Company	Function	Cost	Cumulative cost
Chinese textile mill	Raw material	1	1
Chinese sewing factory	Manufacturing	2	3
Chinese factory boss	Margin boss	0.2	3.2
French brand	Design	0.1	3.3
	Transportation	t	3.5
	Customs	0.5	4
Chinese state factory	Quotas	0-0.5	
French brand	Distribution	20	24
French brand	Market studies	5	29
French brand	Advertising	15	44
French brand	Profit	6	50

Source: J. Ruffier, "China Textile in Global Value Chain," Centre d'Etudes Françaissur la Chine Contemporaine, Hong Kong (CEFC), (2011:12) p 9.

At the moment, judging from the example of the French brand name jeans, the pattern in apparel appears to be roughly similar to that in electronics, except that slightly more of the total value (6-8 per cent) is added in China. As Gereffi and Frederick show, the key nodes in the R&D chain, especially in fabric and machinery,[73] design (brand), marketing (brand), services and retailing, continue to be located in the developing countries.[74] It is possible that Chinese firms will develop (are possibly developing) some brands for the internal market, but even Japan has had difficulty in developing globally recognized apparel brands. Judging from Italian data, European apparel exports are based on branded high-fashion clothing destined for high-income consumers globally.[75] There is also evidence that this high-end activity will be retained in Italy and, probably other high-end production locations, even as commodity apparel production is likely to continue to expand offshore. In the low-end, unbranded clothing segments that supply firms such as Wal-Mart, profit margins for suppliers are extremely low and, as Gereffi observes, the power, control and value capture are with the large retailers. These large retailers pay very low wages to their sales personnel, however, the top management, marketing, information technology and other staff, all located in developed countries, are well compensated.[76]

E. Shoes

Along with garments, shoe production was a very early candidate for offshoring. For example, early in its history, Nike offshored athletic shoe production to Japanese firms. However, as with other fashion goods, there is a global division of labour, and much of the design activity remains in developed countries.

For example, the Danish firm Ecco which sells high-end comfortable shoes, until recently was confined almost entirely to developed countries.[77] As of 2008, only 553 of its total 9,657 employees were located in Denmark, and it continues to produce 90 per cent of its shoes in factories around the world. In addition, its value chain is, in certain respects, surprising. For example, Ecco is among the five largest producers of leather worldwide, but the majority of the rawhides originated from Germany, France, Denmark and Finland.[78] Ecco's tanneries in the Netherlands (it also had tanneries in Thailand and Indonesia)

[73] To illustrate, in the first half of 2011, China, the largest market in the world for textile machinery, exported US$ 1.056 billion worth or an increase of 36.15 per cent, while importing US$ 2.8 billion, an increase of 48.48 per cent ["In the First Half Slowdown in China's Textile Machinery Import and Export," Free Press Release.com, September 6, 2011, www.free-press-release.com/news-in-the-first-half-slowdown-in-china-s-textile-machinery-import-and-export-1315291439.html (accessed February 2, 2012)].

[74] G. Gereffi and S. Frederick (April 2010), 15, www.ds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2010/04/27/000158349_20100427111841/Rendered/PDF/WPS5281.pdf (accessed February 2, 2012).

[75] See, for example, A. Brun, F. Caniato, M. Caridi, C. Castelli, G. Miragliotta, S. Ronchi, A. Sianesi and G. Spina, "Logistics and Supply Chain Management in Luxury Fashion Retail: Empirical Investigation of Italian Firms," *International Journal of Production Economics* 114 (2008): 554-570; P.V. Capello & D. Ravasi, "The Variety and the Evolution of Business Models and Organizational Forms in the Italian Fashion Industry," Business and Economic History 7 (2009): 1-18, http://www.thebhc.org/publications/BEHonline/2009/capelloandravasi.pdf (accessed February 2, 2012).

[76] G. Gereffi, "Global Value Chains and International Competition," *Antitrust Bulletin* 56, No. 1 (2011): 37-56.

[77] B.B. Nielsen, T. Pedersen and J. Pyndt, "ECCO A/S—Global Value Chain Management" (Version: 2008-03-10).

[78] Ibid., 4.

supply leather to its shoe factories in Portugal, Indonesia, Thailand, Slovakia and China. According to Neilsen et al., most of the product development and design remained in Denmark.[79] In contrast, Ecco's most important competitors, Timberland (United States.) and Clark's (United Kingdom) had outsourced most of their leather production. Another Italian competitor, Geox, retains R&D and design in Italy but has its largest, company-owned production facilities in Romania and a significant subcontracting relationship with a large Chinese producer.[80]

In a study of two Italian shoe-producing districts, one of which produced high-price, fashion-driven shoes and the other produced low-price shoes, Alicia Amighini and Roberta Rabellotti found two interesting tendencies.[81] The district producing low-priced shoes was offshoring an increasing number of links in the value chain to low-wage countries. In contrast, the district producing high-price shoes was experiencing functional downgrading as the fashion and design functions were being moved to the large luxury design houses in Milan. In other words, the design function remained in Italy, but moved from the district. However, the district did not experience production offshoring, and, in fact, some of the luxury design houses are integrating the local shoe firms as subcontractors so as to better control quality. Also, these firms were offshoring certain low-value production activities. The lower-price district was rapidly offshoring its production abroad, in particular, in this case to Albania.

Although very high-end shoes can be produced in developed countries such as Italy, the now-ubiquitous athletic shoe is produced in a number of countries, with China the predominant production location. However, as is the case with clothing, while R&D, design and marketing are located in developed countries (for United States brands in the United States and for Adidas and Puma in Germany), production is located abroad. It seems likely that the direct labour costs are similar to those in garment production. For example, in 2004 a global rights organization, which claims to have had access to internal Puma documents, found that the Chinese worker was paid US$ .35 per hour and that the direct and indirect labour contribution for a pair of shoes was US$ 1.16. Using customs documents, these campaigners suggested that the total manufacturing input cost, including labour, was between US$ 3.41 and US$ 7.16 on a shoe that retailed for US$ 70.[82] Although there is no way to verify these calculations, they are roughly similar to those in other industries, particularly apparel, and certainly suggest that the preponderance of the value capture is not at the production stage.

Some scholars, such as Gereffi et al., have found opportunities for industrial

[79] Ibid.

[80] A. Camuffo, A. Furlan, P. Romano and A. Vinelli, "Breathing Shoes and Complementarities: Strategic Innovation in a Mature Industry," *International Journal of Innovation Management* 12, no. 2 (2008): 139-160.

[81] A. Amighini and R. Rabellotti, "The Effects of Globalization on Italian Industrial Districts: Evidence from the Footwear Sector," paper presented at the Conference on Clusters, Industrial Districts and Firms: The Challenge of Globalization, Modena, Italy, September 12-13, 2003.

[82] C. Kernaghan,"Puma Workers in China: A Joint Report of the National Labor Committee and China Labor Watch" (November 4, 2004), www.globallabourrights.org/reports?id=0095#LaborCost (accessed January 30, 2012).

upgrading in apparel, and, presumably, by extension, shoes, yet they seem limited by the powerful control exerted by the brands and large retailers on the entire value chain.[83] Nonetheless, in the production locations, in particular, China, there are and continue to be opportunities for backward integration, especially in textile production. At the low end, this might be actualized by foreign firms that establish the far more capital-intensive and skill-intensive textile production facilities. Also, there should be opportunities in the machinery fields, such as industrial sewing machines. Upgrading into R&D, design and marketing (except for the domestic market and developing country export markets) will be difficult.

As is the case with apparel, the value capture in these chains is concentrated in the headquarters, which is often the location of the design, marketing, logistics and management staff. However, the trade statistics might not reflect this concentration of value capture in the developed country.

F. Machine tools

Machine tools present an interesting case. Because they are a capital good, they are not, generally speaking, mass produced in quantity, as are consumer goods. As defined in the trade statistics, machine tools are confined to machines such as plastic injection molders and those that cut and shape metal. As a category, they can be used to comprise the dramatic variety of machines that are capital goods, including rock drills, paper machines, printing presses, semiconductor steppers and printed circuit board insertion machines. These machine tools embody deep technical and product-specific knowledge that comes from both engineers and, frequently, skilled crafts people. The general tendency has been for developing countries, particularly China, to increase its production and consumption of machine tools (see tables 14 and 15). Because machine tools are used to manufacture other goods, increasing consumption of machine tools is an excellent indicator of where global manufacturing production is increasing. By any standard, the increased Chinese production of machine tools is noteworthy, and in 2010 China surpassed Germany by value in the production of machine tools. Further, Japan also increased its global production share, as did the Republic of Korea and Taiwan Province—likely because of exports to China, in particular. According to Gildemeister,[84] Japan and Germany were the two leading exporters.

[83] Gereffi et al. (2011).

[84] Gildemeister, "Development of the Machine Tool Industry", 2010, http://reports.gildemeister.com/en/2010/business-report/business-environment/development-of-the-machine-tool-industry?p=1/ (accessed February 2, 2012).

Table 14. Worldwide production of machine tools by total value and national share, 2009 and 2010

	Global production 2009 (%)	Global production 2010 estimate (%)
Total value in euros	36.1 billion	45 billion
China	20	22
Japan	14	19
Germany	22	16
Italy	10	9
Republic of Korea	6	8
Taiwan Province	5	6
Switzerland	4	4
United States	4	3
Other countries	15	13

Source: Gildemeister,"Development of the Machine Tool Industry," 2010, http://reports.gildemeister.com/en/2010/business-report/business-environment/development-of-the-machine-tool-industry?p=1/ (accessed February 2, 2012).

Table 15. Worldwide consumption of machine tools by total value and national share, 2009 and 2010

	Global production 2009 (%)	Global production 2010 estimate (%)
Total value in euros	36.1 billion	45 billion
China	30	35
Germany	12	8
Republic of Korea	5	7
Japan	6	6
United States	6	5
Italy	6	5
Brazil	3	3
India	3	3
Other countries	29	28

Source: Gildemeister (2010).

In terms of consumption, China was by far the global leader. It consumed 30 per cent of global production in 2009 and 35 per cent in 2010. Interestingly, Germany's share of consumption fell by 50 per cent, while the Republic of Korea's consumption also increased significantly. Here again, as was the case with production, East Asia continued its growth, with China leading the way. Deeper concerns in Germany and Japan should be the long-term tendency toward Chinese improvement.

In machine tools, different countries have different roles into the global economy. According to one report, Japan's industry competes across a broad spectrum of markets (see figure 2). For these reasons, Japan is experiencing competition from other Asian countries more directly than are Germany and the United States. As Masao[85] indicates, many of the largest Japanese machine tool makers are already producing in China, though many of the Chinese factories are producing the low-end, mass production machines that are price competitive market segments, while the higher value-added, newer machines continue to be designed and produced in Japan. It is likely that the same is true for European manufacturers. This suggests that the highest value-added activities are retained in developed countries. However, if developing country factories can, over time, develop similar workforce skill levels and continue to offer low wages, even knowledge-intensive sectors such as machine tools might move offshore.

In many respects, the machine tool industry resembles the other ones studied here, but with its emphasis on innovation, high quality, and, at the higher end, service provision, and the high-end of the industry remains concentrated in high-cost countries such as Japan, Germany, the Nordic countries, and high-cost regions such as northern Italy. Although low-end commodity production is moving offshore, particularly to China, the high-end production and presumably higher value-added portion of the value chain continue to be located in developed countries and further research is likely to show specific industrial clusters that specialize in particular types of machine tools.

G. Concluding remarks

Remarkably, despite the fact that these sectorial reviews covered a wide variety of industries, there was a remarkable degree of overlap.

1. There has been a dramatic shift in production for re-export to developing countries. yet the value captured in there has been quite limited. For branded, high-design, or technology-laden products, the preponderance of value appears to be captured by those controlling the brand and creating the designs/technologies. In the cases in which the product is almost entirely commoditized, Gereffi[86] has theorized that the buyers (actually the retail or distributor intermediaries), such as Wal-Mart, probably appropriate most of the value.

2. In some cases, key component makers can capture significant value, and these components are often imported to the country where final assembly is performed. For example, Samsung, in particular, but also Korean, Taiwanese, and even Japanese producers can capture sufficient value to support manufacturing in their high-cost, or increasingly high-cost, environment. Although this

[85] H. Masao, "The Uncertain Future of Japan's Machine Tools Industry," Nippon.com. (December 7, 2011), http://nippon.com/en/currents/d00007/ (accessed February 1, 2012).

[86] G. Gereffi, "The Organization of Buyer-Driven Global Commodity Chains: How U.S. Retailers Shape Overseas Production Networks," in *Commodity Chains and Global Capitalism*, ed. G. Gereffi and M. Korzeniewicz (Westport: Greenwood Press, 1994), 95-122.

study does not confirm this speculation, it is likely that European machinery producers have a similar advantage.

3. Technologically sophisticated or complex products for which quality is very important, such as automobiles and machine tools, are still being produced in developed countries. Although, in some cases, low-end mass-market machine tools might be produced in low-wage countries, the high-end activities will likely continue to be located in the home market.

4. There is a regionalization dynamic at work, in which Eastern Europe, Turkey, and, to a lesser degree, North Africa serve the Western European market. Western Europe is also a major exporter of high value-added products to the world. The North American market is served by Mexico and, to a lesser degree, the rest of Latin America. China and South-East Asia serve Japan, but Asia is different in the respect that it also serves the world.

5. The one overwhelming fact is the increasing role of China in nearly all global manufacturing value chains. More important, Asia, in a wide variety of industries, is developing a sophisticated internal division of labour and trade, whose ultimate reason for being is exporting to the rest of the world.

III. ICT-enabled services: the implications for manufacturing[87]

John Zysman, Stuart Feldman, Jonathan Murray, Niels Christian Nielsen, and Kenji Kushida[88]

A. Introduction

The character of competition in manufacturing has been profoundly changed by the information and communications technology (ICT) transformation of services. The "manufactured product" is increasingly a commodity that can be purchased in the global market, while ICT-enabled services embedded in the products increasingly define the value proposition. Services are increasingly the way that firms pursue value-added activities to avoid ever-faster commoditization of products—that is, to avoid competition based solely on price when market offerings are relatively similar. The differentiator is no longer the product but, rather, the function that it can provide. The following examples illustrate this evolution. A mechanical crane with intelligence embedded in an ICT system can become an instrument of port management. Apart from the electronic controls for the core auto functions and the remarkable entertainment system, vehicles with global positioning systems (GPS) and communications, such as General Motors' OnStar system, become networks as part of a safety and traffic management system. Indeed, in the current era, manufacturing is offered as a service, with examples ranging from Taiwanese "fabless" semiconductor manufacturing firms to a company such as Foxconn, which manufactures electronic products under contract to brand-name suppliers (original equipment manufacturing (OEM)), including Apple. All those offerings hinge on ICT, whether to manage the supply change or to translate design into production. The consequence is that the blurred distinction between products and services blurs further, as manufactured products are increasingly embedded in and recast as services offerings. Thus, we note as we begin that the classic distinction between goods and services has always been murky and the statistical categories

[87] This chapter is an adaptation of "Services with Everything: How ICT Transformed Services from Sinkhole to Productivity Driver," in *Innovation in Public Governance*, ed. A.-V. Anttiroiko, S. Bailey and P. Valkama (Amsterdam: IOS Press, 2010), which in turn was drawn from "It Draws on Storm," BRIE Working Paper 187, April 6, 2010. In addition to the discussions among and experience of the authors, the article has also drawn heavily on the research efforts of Bartholomew Watson and Derek Wong at BRIE.

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unsatisfactory. Now, as services rest increasingly on ICT systems that are designed and built, and products embedded with ICT become part of service networks, the distinction increasingly evaporates. We will be better served by considering issues about manufacturing and ICT-enabled services as elements of a larger category: "production."

This chapter considers the implications of the current fundamental ICT-based transformation of services for traditional discussions of manufacturing. The transformation—driven by developments in ICT tools, the uses to which those tools are being put, and the networks on which they run—is influencing the place of manufacturing in global competition and the ways in which firms compete, collaborate, organize and govern themselves.

B. The algorithmic transformation of services

Services were once considered a sinkhole of the economy, immune to significant technological or organizational productivity increases.[89] Now, they are widely recognized as a source of productivity growth and dynamism in the economy that is changing the structure of employment, the division of labour, and the character of work and its location.[90] Yet the actual character of this transformation is often obscured by the increase in jobs labeled as services and by a focus on the digital technologies that, certainly, are facilitating this transformation.[91]

B.1. The algorithmic revolution

The application of rule-based ICT tools to service activities transforms the services component of the economy, altering how activities are conducted and value is created. We call this the algorithmic revolution.[92] In the algorithmic revolution, tasks underlying services can be transformed into formalizable, codifiable, computable processes with clearly defined rules for their execution. Processes with clearly defined rules for their execution can be unbundled, recombined and automated. When activities are formalized and codified, they become computable.[93] The inexorable rise in computational power and the development of sensor technology means that an ever greater range of activities is amenable to expression as computable algorithms, and a growing array of service activities are reorganized and automated.[94] To repeat the essential point, the codification of

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[89] For example, William Baumol wrote in the 1960s that it still takes the same amount of labour to play a Beethoven quintet (Baumol and Bowen, 1966; Baumol, 1967). However, in the past years he has come to recognize the power of the ICT transformation of services (Baumol 2007).

[90] Triplett and Bosworth (2004).

[91] The conventional view, summarized effectively by the National Academy of Sciences, is that growth since the mid-1990s was largely driven by the rapidly falling cost of processing power (following "Moore's law," which predicted that the number of transistors in integrated circuits—roughly, processing power—would double every two years) and heavy corporate investments into ICT (Jorgenson and Wessner 2007; Jorgenson, Ho and Stiroh 2005).

[92] Zysman (2006).

[93] To illustrate, bank ATMs have automated simple bank transactions, and consumers increasingly book airline tickets and car rentals online. In major enterprises, payroll processes have been reorganized and largely automated.

[94] Nordhaus (2202).

service activities allows the rapid replication, analysis, reconfiguration, customization and creation of new services. It allows business models, extended with ICT tools, to become more productive and entirely new business models to be created, offering services previously impossible at any price. The algorithmic revolution in services is profoundly changing how firms add value.

Firms find that existing activities, when converted into computable processes, often take on new purposes and create new forms of value. For example, the act of making a purchase at a supermarket or retailer has been transformed from a simple monetary transaction to a data-generating activity. At the beginning of the application of ICT to retail, inventory was monitored.[95] Then, increasingly fine-grained information of not only inventory but customers began to be collected for analysis. Retailers could capture consumer preferences and consumption patterns as well as to manage inventories and supply chains and sometimes to sell generated data to third parties. Accenture, for example, transformed its data management service into a new, value-added service of data monitoring. Its initial service, offered to pharmaceutical companies, was to manage their clinical trial data. Accenture then leveraged its ability to analyse this data by offering pharmaceutical firms a service to monitor the reactions of test subjects to drugs.[96]

This unbundling of service activities is the counterpart to the decomposition of manufacturing, in which modularity in product design enabled manufacturing supply chains to be broken apart and spread across multiple corporate boundaries (outsourcing) and national borders (offshoring).[97] In both cases—the unbundling of services and decomposition of manufacturing—the recomposition critical to sustaining market position and driving productivity. The recomposition of the products, the final offerings, highlights the need for constant innovation. If products and their constituent elements stay the same, they are rapidly and constantly commodified.

B.2. ICT-enabled services as a response to commoditization of traditional manufactures

The effort by firms to address intense global competition and commodization of their offerings is the most powerful pressure driving the reorchestration of services with ICT tools. Because of the newcomers from diverse countries and the rapid diffusion of technology, many products face intense price competition. That is, the products become commodities, largely interchangeable from their rivals and hence competing principally on price, even if they become more sophisticated. As firms seek to avoid ever-faster commoditization, many are repositioning the role of services in their core business model. Increasingly, firms see services as the solution to creating defensible positions in markets.[98]

[95] Borrus and Borrus (1985).

[96] "Outsourcing: External Affairs," 2007.

[97] Borrus, Ernst, and Haggard (2000); Baldwin and Clark (2000).

[98] For example, see Frei (2008); Shankar, Berry and Dotzel (2009).

These same ICT tools facilitated the communication that encouraged an extension of competition. New competitors from countries seeking to industrialize were able to enter the marketplace as a result. The new competitor usually began with basic products, either borrowing technology and producing for their home markets or sending basic exports to wealthier, more advanced countries. Meanwhile, companies from the advanced countries moved production offshore. Sometimes, those advanced country firms produced offshore themselves; sometimes they contracted with other firms to produce offshore for them, outsourcing abroad. As ICT tools became ever more sophisticated, producing both goods and services abroad, developing products abroad and managing the complex operations involved, all became easier and less expensive. The consequence was straightforward. Competition for standard products—products that were, in essence, commodities differentiated by price or by branding—became ever more intense. The competitive pressures that have accelerated commoditization in a global, digital era are pushing firms to seeking value in ICT-enabled services.

Firms' hardware offerings are increasingly enhanced in value by ICT-enabled services offerings. Apple's iPod is more than an attractively designed mp3 player. Its integration with the iTunes software was critical to its commercial success and Apple's online music store revolutionized the way in which music is sold. Komatsu, a Japanese construction machinery firm, sells products with embedded sensors; these sensors send detailed information to the company's headquarters not only about the deterioration of parts but about fuel usage and other information. As a result, Komatsu can notify its customers in developing countries if fuel is being siphoned and it can even remotely halt the operation of machines if lease payments are overdue. Finally, Komatsu can use data from the levels of usage of its machines to generate supply-demand predictions for countries or regions in which statistics about economic trends are unreliable. Similarly, John Deere offers agricultural equipment that embeds an array of services. Location-referenced soil samples can be collected, analysed and sent wirelessly to a remote database, which both helps "map" the fertilizer applied and adjust the fertilizer mixtures in real time.

Some firms go further, shifting their core businesses from selling products to offering services, often delivered via ICT networks. IBM, for example, transformed itself from a product company in which support services provided a competitive advantage to a services company that embodies products in its offerings. Emblematic of this transformation was IBM's sale of its Thinkpad notebook computer division to the Chinese company Lenovo and its acquisition of PricewaterhouseCoopers' consulting arm. While it still derives significant profits from its hardware offerings, IBM's central focus has been on its service offerings, which include management consulting, running firms' ICT operations and providing a wide range of functionality for firms with its software. IBM's most recent "Solutions for a smarter planet" campaign, with a wide variety of target customers, ranging from banking, buildings, education and energy, to food, health care, government, oil, retail, traffic and water, demonstrates just how far the firm has gone in focusing on services.

A few examples offer engaging stories, beginning with wireless fasteners. Helical screws—screws that have a thread cut into them, so familiar today—were a revolutionary technology when introduced widely in the 1400s. They were handmade by craftsmen until the invention of a screw-cutting lathe in the late 1700s. Later, the mechanical production of screws and bolts played a major role in the Industrial Revolution. As mass production along the lines of Henry Ford's factories took hold in the early 1900s, an integrated nut-and-bolt system was invented, creating the tooling and nut-and-bolt mechanism that could be integrated into mass production environments. TZ Group, an Australian company, took the next step in fastening technology. It designs wireless-enabled fastening systems, meaning that potentially labour-intensive tasks such as reconfiguring aircraft seats can be made more efficient. These wirelessly controlled "nuts and bolts" enable a technician to remotely unlock any number of seats to be reconfigured, and, once repositioned or replaced, they can be relocked on command. Similar systems are now being developed for use in many other industries, from automotive and marine applications to medicine and defence.

Consider the Chilean mining company CODELCO, the world's largest copper producer. To increase worker safety and improve productivity, it has embarked on a programme to retrofit heavy excavation equipment for robotic control through high speed, low latency telemetry. This capability eliminated the need for workers to be collocated with the equipment, enabling miners to move outside the mine into safe, clean working environments. This remote control capability also dramatically reduced the number of miners required to deliver the same output capacity. These initial steps open up the possibility to view mining as a service business, with remote-controlled operations offered to other companies and in other countries.

Products can be transformed into services when delivered via ICT networks. All these stories show that the traditional distinctions between products and services, never evident in the first place, are becoming ever less clear. For example, software, which used to be a product distributed on physical media, is now increasingly repositioned as a service. Quicken, a software product if purchased as a CD in a box, becomes a service if the same software engine runs on the Internet, via paid access. Enterprise software for large companies increasingly takes the form of "Software-as-a-Service" (SaaS), with software delivered via the Internet and the customer is billed by usage. Even products as basic as data servers and computer processors are transformed into services delivered over ICT networks. Many firms are offering remote storage and processing power, applications and software development platforms, with pay-as-you-go payment systems, known collectively as "cloud computing."[99]

Products can become portals to services or are embedded in services. Apple's iPod is at once a product and a portal to its online music store. Likewise, Apple's iPhone is both a product and a portal to Apple's services platform; as cellular handsets are increasingly commoditized, the iPhone's capability to act as a

[99] Kushida, Breznitz and Zysman (forthcoming). See also Armbrust et al. (2009).

conventional phone is no longer its primary competitive attribute. Similarly, Amazon's electronic reader, the Kindle, is a product, but its primary value is in its integration with Amazon's online bookstore and magazine offerings.

Conventional sectoral distinctions are collapsing into "value domains." The digitization of information brings previously physically distinct products and sectors into competition with one another in less clearly defined customer bases.[100] The block of plastic that we call a phone morphed into a smartphone that provides a variety of different digitally-based functions and services.

Consider the evolving competition surrounding cellular handsets, digital cameras, portable music players, music distribution and software. Until the early 2000s, Nokia competed in cellular handsets against firms such as Motorola, Ericsson and Japanese and Korean manufacturers. However, as digital cameras became embedded in cell phones, manufacturers began to offer a function in the smartphone that implicitly competes with basic camera sold by companies such as Canon, Nikon and Casio.

As digital music players became increasingly popular, led by Apple's iPod and its iTunes online store—which proved that consumers were willing to pay for legally downloaded music—Nokia, other manufacturers and cell service carriers entered this value domain. Cellular handset manufacturers began to incorporate digital music player capability into their products, offering digital music services, such as Sony Ericsson's Walkman brand handset and Nokia's one-price, unlimited-use music licensing included in its "Comes with Music" service. Cellular carriers around the world began to offer their own music downloading services. Microsoft, which began as a software company, also entered this domain, offering its own mp3 music player and music downloading service.

As the computing performance of cellular handsets improved, bringing them closer to that of computers, they became an entry point for a different set of firms interested in the devices' performance as a portal for online services. Apple's entry into the cellular handset business, the iPhone, was not simply a handset but a portal for an online mobile applications store. Microsoft already had mobile handset operating system offerings—it was on its sixth version when Apple introduced the iPhone—but Apple was first to recognize the potential of linking the handset to a services platform. Carriers in countries such as Japan and Korea were already offering mobile Internet service platforms, which were tightly linked to handset offerings, but these services were confined to their domestic markets.[101] More recently, Google moved from web-based services to the handset operating system and handset markets as well, starting with its Android platform, followed by a handset offering.

Thus, competition within distinct sectors has extended into competition over "value domains." More players are involved and there is less clarity over the boundaries of previously distinct product and user categories.

[100] Many thanks to Erkki Ormala of Nokia who first made this argument at a lunch in Helsinki.

[101] Kushida (2008).

B.3. The story has just begun: technology drivers: evolving computing platforms and captured advantage[102]

The technology drivers of the services transformation include the exponential growth in computing power, the increasing speed of networks, evolution of software and the progression of computing platforms. Computing platforms evolved along two dimensions—from stand-alone to network and from mainframe computers to PCs. The result was an ever-increasing power to digitize information and then process, store and transmit information in digital form.[103] Each technology step opened new possibilities for the application of ICT to services. The increasing processing power, expanded storage and connectivity created a variety of opportunities. All that brought greater functionality to the desktop, but it also meant small phones, increasing connectivity and distributed sensors embedded in everything. The advent of the Internet as a platform for the delivery of services and business activities ushered the transformation of services into the contemporary era.

An evolution to the next computing platform is currently under way. Cloud computing will spark another major round of innovations and new entrants. Cloud computing, in essence, offers: *(a)* computing resources (such as applications, services and data) on demand via networks; *(b)* which can be scaled up or down rapidly, according to the users' needs (providing users with the illusion of infinite scalability); and *(c)* are often offered as pay-as-you-go programs, requiring no up-front commitment.[104] For users, cloud computing allows computing to become an "enhanced utility."[105] Firms can avoid the capital expenditure of building their own data centres, instead paying for computing resources as are needed. Barriers to entry into computing-intensive areas are lowered, the ability to experiment is increased and it becomes easier than ever for startups and new entrants to scale up rapidly and become major players.

The technologies, of course, do not create their own use or generate their own value. The services transformation is not simply a technology story; rather, the advantage of ICT tools must be captured by organizations. The argument put forth by Stephen Cohen, Bradford DeLong and John Zysman to understand the first phase of the ICT revolution still stands: "At each point in the past forty years the critical step in the transformation of technical potential into economic productivity has been the discovery by users of information technology of how

[102] Parenthetically, we consider the financial debacle of 2008 to be the first major crisis of the information era. Whatever its other implications, it will stand as a stark demonstration of the new logic of value creation, the transformed character of the service economy, and—paradoxically—the heightened importance of human judgment in a world where electronic tools for gathering, analysing, and managing information are more ubiquitous and powerful than ever.

[103] The combination of today's computer hardware, vast interconnected networks, and enormous databases has enabled the development of entirely novel sets of algorithms that mine data and draw inferences using statistical techniques from large data sets. They have started to replicate many of the analytical tasks previously done by skilled knowledge workers; the resulting change, which is as much qualitative as quantitative, is radical.

[104] Since cloud computing is still new, there is still disagreement and confusion over definitions. The characteristics here are from Armbrust (2009).

[105] See Kushida, Breznitz and Zysman (2010).

to employ their ever-greater and ever-cheaper computing power to do the previously-impossible."[106]

Innovative lead users, in the form of large and small firms discovering new uses for information technology, were critical. Information technology was adopted either to solve a particular problem or to cut costs. Innovative users then discovered new uses. For example, Citibank took advantage of flat-rate telephony, moving its back offices not only into the entire New York metropolitan area but all the way to South Dakota. The organizational shift enabling this move—modularizing the back-office operations—facilitated moving select back-office operations much farther, for example, to India. Continual organizational experimentation and innovation, adopting new technologies and finding new business models and services possibilities, will continue to drive the services transformation.

In sum, the pressure to escape commoditization is driven by the interplay of technology, organizations and competition in a global, digital world, and evolving computer platforms are driving the services transformation.

C. Making sense of the ICT-enabled services transformation

The services transformation is pervasive. To identify the implications for manufacturing, we need some tools to sort through the developments. First, we distinguish the underlying services activities, placing them on a spectrum ranging from irreducible to automated. We then consider the implications for productivity gains for each type of activity and lay out the limits of the transformation—a case for the enduring role of human judgment. Then we turn to a range of transformations in the business models built on top of these services.

There is a range of services activities to consider, from irreducible to hybrid to automated (see figure II). The spectrum proposed here applies to government activities as well as firms.

Figure II. The services spectrum

Irreducible services	*Hybrid services*	*Automated services*
Rely on humans to deliver services, which are typically created at the same time and in the same place they are delivered.	Rely on a combination of humans and electronic tools to deliver services, using ICT and other systems to leverage or enhance human capabilities. This combination is often constituted as a system.	Rely on ICT or other technologies to deliver services that have been codified, digitized and made available, often using electronic communication or distribution tools.

[106] Cohen, DeLong and Zysman (2000), 15.

Irreducible services rely on humans to deliver them. They are provided strictly by human beings, either because they require personal skills or attributes that only humans can offer or for simple reasons of practicality and cost. Examples include the services provided by hairdressers, judges, psychologists and priests. In most cases, irreducible services are created at the same time and in the same place where they are delivered and used; such services cannot truly be said to "exist" apart from their delivery by humans in a particular moment and location. Irreducible services originally constituted the full range of services available in the economy and they still make up the majority of services sold. The constant evolution and growing power of ICT tools, however, constantly increases the range of services that can be "transformed" into automated or hybrid services.

By contrast, ICT automated services rely on digital ICT to manage information and deploy it in ways that are useful and valuable to customers. The services provided by a bank automated teller machine (ATM), an Internet travel agency, or electronic systems for collecting road and bridge tolls are familiar examples.[107] Some automated services compete with and threaten existing manual services or extend their reach. In one sense, eBay's online auctions compete with traditional suppliers of human-based auctions services, such as Sotheby's, Christie's and hundreds of local auction houses. However, their real business success rests on extending the auction model to products and communities that the model could never reach without ICT tools.

Other automated services offer entirely new services that could not be provided manually—for example, Google's online search capability can perform functions analogous to those of a traditional human librarian or research assistant, but with a degree of speed, efficiency, accuracy and thoroughness that no human service provider could ever hope to duplicate. On-demand delivery of video content by companies such as Netflix allows consumers to stream content previously available only on DVD or through illegal downloads.

Finally, hybrid services combine human and machine-based capabilities, either harnessing technology to improve and leverage the abilities of people or depending on human talents to augment, deliver, customize, personalize, or otherwise add value to automated services. They are not simply services in which some of the information involved in the process or transaction is captured electronically—such as a massage therapy business that uses digital software to manage reservations and accounting. Rather, a central element in the creation of value is digitally processed.

A growing proportion of the most valuable and popular services are now hybrids. For example, accountants often rely heavily on software containing significant information about tax rules, bookkeeping systems and financial principles and are able to store, analyse, update and manipulate large amounts of data with ease, speed and accuracy. However, they supplement the power of the software

[107] But not all automated services use digital ICT: for example, a self-service Laundromat is an automated provider of services that typically does not employ ICT, except to the extent that modern washing machines use microchips to control some functions.

with personal judgment that helps them provide advice and insights suited to particular situations. Similarly, travel agencies handle most transactions digitally, but use human agents to handle complex cases and particularly high-value customers.

This system is highly dynamic, with particular services, service companies and even entire industries moving, rapidly or slowly, from one position on the spectrum to another. As new technology and business systems are devised, the nature of possibilities continues to evolve. Services once practically unobtainable—access to vast stores of information now provided by a routine web search engine, for example—can now be obtained at virtually no cost in terms of time, money or effort. The local limitations that constrain the availability of traditional human-delivered services are also reduced or eliminated by digitization.

C.1. The services spectrum and potential for productivity gains and transformations

Fully automated systems, the evidence suggests, offer the greatest potential productivity gains. Because they rely on digital systems, the power, efficiency and affordability of algorithmic services can be expected to improve in accordance with exponential increases in computing capabilities. As chips improve and multiply, and the networks that they form become exponentially more powerful, the possibilities for fully automated digitized services expand dramatically.

The deepest economic transformations are occurring in the hybrid sector, which interweaves ICT-networked, sensor-enabled products, such as nursing tools or cranes or cars, with human delivery and judgment. The value of hybrid services depends on having human capabilities augmented by increasingly sophisticated ICT systems.

Existing data on productivity, organized by traditional industrial sectors, is not optimal for measuring productivity increases across our division of activities: automated, hybrid and irreducible. A rough estimate, taking select industries in which the bulk of activities fit into one category rather than another, is shown in table 16.

Table 16. Productivity increases, United States (1995-2003), elected industries

Activity type	*Industry*	*Productivity increase*
Automated	Telecommunications	70.5%
Hybrid	Retail trade	53.0%
	Financial intermediation	66.2%
Irreducible	Business activities (consulting)	16.9%

Source: Groningen 60-Industry database.

C.2. The limits of transformation: the need for human judgment

The outcome of the transformation rests not on the inherent unfolding of the technologies but on the policy choices and the talent and skills that we develop. It is crucial for policy and business strategy that these technologies can empower human creativity, and only by capturing that possibility can distinctive advantage be generated. The ultimate limits of the domain of the computable have been a significant source of debate among many observers, including the authors of this chapter. One extreme view is that the domain of the computable will eventually push out human judgment altogether. The opposite view is that human knowledge will continue to dominate—that core facets of knowledge can never be reduced to algorithms. Our view is that, while the domain of human activity that can be codified and automated increases, human judgment will continue to be critical.

Now that we have covered the spectrum of how services activities are transformed by the algorithmic revolution, let us now turn to how they affect business models built on top of service activities.

C.3. Manufacturing: a range of services business model transformations

The algorithmic revolution makes possible a range of business model transformations. Many business models entail delivery of services. Others are extended or transformed by the underlying tools available to them (see figure III). These possibilities suggest the range of business governance questions that governments will need to address.

Figure III. The range of business model transformations

At one end, firms can use ICT services to enhance traditional business models, often by increasing their efficiency. For example, life insurance was among the first industries to transform its business models with the massive application of computing resources and algorithms. Wal-Mart's early and extensive use of ICT to link suppliers and distribution radically increased its operational efficiency.

Firms can also extend traditional business models with ICT-enabled activities. An outsourcing firm, such as Flextronics, becomes a company providing manufacturing services. The Chilean mining company mentioned earlier took its traditional business of operating mining machines and shifted it to ICT-enabled remote operations. Now that its machines are remotely operated, it can offer remote mining operations as a service worldwide. In this way, existing firms often progress from one step to the next; they first enhance their traditional business model to improve efficiency and then move to extending the business model in new ways.

At the far end of the spectrum, entirely new business models are invented. The Apple iPhone and iPad applications structure created a truly new business model for media, designing physical objects as a portal to access network services. Google, outside our focus here, is the prime example, linking advertising revenue to search functionality. An interesting example of an entirely new business model can be found in virtual currency; users using real money to purchase virtual gifts, avatars, or other virtual goods in an online game or social networking site. Some estimate that the virtual currency market in the United States exceeded US$ 1 billion in 2009.[108] There are relatively few examples, but many hope to discover and develop the next completely new business model.

C.4. The services dilemma and the necessity of continuous innovation

We have seen that the ICT-enabled services transformation involves both including a services component in the business model and transforming service activities, particularly routine activities, into computable processes. This is just the beginning of the competitive story. Two matters must be noted. First, the application of ICT to existing service activities, the automation of existing activities, is always the beginning of the story. What one firm automates another firm can copy; the initial "automation" provides short-lived limited advantage. Continuous learning and innovation are therefore required. The final offerings need to be rethought, reconceived and implemented anew. Second, even in radical new services, such as online search or Twitter, which open entirely new domains, the competitive problem is how to maintain advantage. Google's constant introduction of new functionalities and new possibilities is part of its effort to hold its users and, hence, bolster its advertising rates. The algorithmic revolution and the ensuing services dilemma thus continuously pit potential productivity gains against the constant threat of commoditization.

D. ICT-based services: implications and policy debates

D.1. The firm strategy

Firms throughout supply chains must increasingly realize that the value of their products, modules, subsystems and components will increasingly be realized through ICT-enabled services. Even classic manufacturers must learn to design for services. They must consider how the final product, often with embedded services, will be designed, developed and marketed. Final product designers

[108] Walsh (2009).

already have this in mind with defining specifications for the physical products through which the service value will be realized. Consequently, those issues will flow through the supply networks. This will, inevitably, affect specifications and requirements of components and subsystems but must influence the relationship with suppliers and product engineering more generally.

D.2. The policy debate

Even if focused on traditional manufacturing, policy must facilitate the engagement of the broader economy, firms and the workforce in the ICT-enabled transformation. Policy must help firms design and produce for a world of ICT-enabled services embedded in, well, everything; hence, developing an understanding of the impact of ICT on product development and value realization, not just in production itself. Of the many dimensions, we mention two policy areas: *(a)* connectivity—the availability of ICT tools and infrastructure and *(b)* people—the skills and the capacity to implement technology.

Connectivity: By connectivity, we refer broadly to the availability of ICT networks and tools. The notion of connectivity has evolved over time, causing a parallel shift in the potential role of the government in ensuring connectivity. The original notion of connectivity consisted of ensuring universal telephone access, including to remote geographic regions and across all income levels. With the advent of the Internet, connectivity expanded to cover Internet access, with concerns over the "digital divide" between those with and without access. More recently, connectivity was expanded to include broadband speeds, with different countries defining different throughput thresholds. The diffusion of mobile technologies further widens the notion of connectivity, as the Internet may be best accessed through mobile networks, especially in developing countries. Although the notion of connectivity continues to evolve, it is clear that, without connectivity, very little is possible in the way of taking advantage of the production and consumption of digitally transformed services, or producing products and components for these systems.

People skills and capacities: Even if technology and connectivity are available, they are useless without people capable of using and implementing them. Human skills affect what can be done. Although purely routine tasks will become increasingly automated, human tasks remain. There will always be new problems to be solved, new processes to be codified and new services to be automated through the creation of algorithms. For example, in the automation of health care, as medical knowledge advances, new systems must be constructed, new monitoring and intervention patterns will be needed, and human interventions will still ultimately be necessary. An almost endless number of services will also remain that rely on the application of both tacit knowledge and pattern recognition. Competitive companies will continue to depend on human abilities to identify and integrate sources of new knowledge and insight, to communicate this information with others through rich verbal and written interactions, to apply expert judgment based on tacit knowledge and pattern recognition, and to understand the significance of an entirely new problem and devise creative ways of addressing it.

A second implication of the new workforce dynamic notes a shift in the balance between specific skills and general skills. Until recently, the specific skills developed over years on a particular production line or in a particular business function (marketing, finance, design) were vitally important to organizations. Today, the value of such specific skills is rapidly eroding. With the accelerating introduction of new products and new services based on new technologies and new production methods, and with the growing use of IT-driven tools to automate processes that are purely routine, knowledge of "how things have been done" is increasingly perishable. By contrast, such general skills as the ability to understand and cope with the unusual and the unexpected and the ability to learn quickly in ever-shifting environments are becoming increasingly critical. People who can pull together information from various expert systems and knowledge bases, crossing domains and identifying patterns and connections, will create the most economic value in societies. This kind of abstract thinking—the ability to combine sensory data with an intuitive sense of what is right and wrong in terms of the meaning and quality of data—is extremely difficult to reduce to a digital algorithm and will probably remain so for many years to come. Therefore, this uniquely human capability should be emphasized and developed as much as possible in both educational systems and knowledge-management programmes at the company level.

The implications for worker training and recruitment programmes have yet to be worked through. How does a country or a company maintain the capacity to sustain vital skill domains (e.g., cutting metal) when the technologies and techniques dramatically change, as when lasers replace diamond-tipped tools in metallurgy? It is not just a matter of hiring smart, well-educated people but about hiring people whose greatest skill is the ability to develop, absorb and communicate ever-changing knowledge. As futurist Alvin Toffler puts it, "The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn."[109]

A more general policy conclusion emerges: The development and deployment of ICT-enabled services should be considered a form of production intimately tied to the local success of what is conventionally called manufacturing. In fact, the ICT-enabled systems must be built, and the products that are part of the networks must be imagined, designed and built. This raises several issues. First, ICT-based services have to be built and produced, or, at least the ICT systems have to be designed, developed, built and implemented. The tools, including software, have to be "built," and the online services have to be "constructed." Consequently, they are very open to innovation and productivity increases. From a policy standpoint, the question is how to conceive, design, develop, build and deploy the new system. The "good" jobs, ones with high-value added functions, are in the innovative development and deployment of these systems. Policymakers should employ strategies that will help communities and firms to develop the competencies required for this new form of production. The continuing debate in political, economic and public policy circles about the relative value

[109] Gibson, Rowan and A. Toeffler (1998).

of manufacturing jobs and service-sector jobs is increasingly irrelevant to policy debates in the real economy. Just as it is inaccurate to assume that manufacturing jobs are secure and well paid, it is also inaccurate to consider service jobs dead-end, low-wage, unskilled positions. This model ignores not only the lawyer and physician but also the computer programmer, the financial analyst and the web designer—each a high-paid, highly skilled service worker. Rather than focusing on the increasingly irrelevant distinction between manufacturing and services, we should recast the conversation. If the word "production" includes not only traditional manufacturing but also the development of IT-based services—with the know-how, skills and tool mastery that they require—then we see that, in this broader sense, production remains of vital importance in the digital age, not just in the traditional manufacturing industries but in the services sector as well. And production workers—including not only assembly-line employees but also many kinds of knowledge workers in service industries ranging from finance, health care and IT to education, media and entertainment—are now more important than ever.

E. Conclusion: governing the transition

By way of summary and conclusion, we argue that the ICT-enabled transformation of services will alter manufacturing and manufacturing competition as it transforms the larger economy. We have shown that the fundamental transformation of services under way is being driven by developments in ICT tools and the uses to which they are being put. The application of rule-based IT tools is transforming services activities, changing how activities are conducted and how value is created. Service sectors have been transformed from a productivity sinkhole to a source of dynamism and productivity growth. The algorithmic revolution enables tasks underlying services to be formalized, codified and transformed, and firms are increasingly turning to services to add value. In-house business functions are available as services, firms are increasingly made up of bundles of services purchased on markets, and manufactured products are increasingly embedded and recast as service offerings. Traditional sectoral boundaries are breaking down as information and service offerings drive previously unrelated firms into direct competition.

We have offered some analytical vantage points from which to understand how the services transformation is unfolding. We introduced a spectrum of services activities, ranging from irreducible to hybrid to automated. While the last of these offers the highest potential productivity gains, we contend that human judgment will continue to be critical. We also introduced a range of business model transformations made possible by the algorithmic revolution, ranging from enhancing the efficiency of traditional business models to extending traditional business models with ICT to creating completely new business models. We showed why the transformation is unfolding now and, so rapidly, by contextualizing it in the competitive pressures from a global, digital era and the evolution of computing technologies and platforms.

For firms and governments, the challenge is to capture the benefits of the transformation. For manufacturing firms, capturing the gains from the implementation of new technologies requires new business models, new organizational strategies and cultivating new skills. It will increasingly require understanding not just how production of manufactured goods is embedded in supply networks but, rather, how the products gain value as part of ICT-enabled service systems. Manufacturing will increasingly turn to embedding products with ICT-enabled services; the conception of manufactured goods often as part of networks and the production processes as part of services. For governments, this scenario requires providing connectivity, ensuring an environment in which the ability to continually learn new skills is fostered, and creating rules to facilitate experimentation and implementation.

IV. The problem of decomposition: industrial policy and growth in a world of phased production

Dan Breznitz[110]

Economists have been evaluating the success of national economies based on the growth of specific national industrial "sectors," whether electronics, information technology (IT), aerospace or textiles. Consequently, we have been equating particular countries with specific sectors; the United States with aerospace, Germany with automobiles and Taiwan Province with electronics. Indeed, even economists who studied clusters, such as Michael Porter, have been looking at specific sectors, arguing that clusters provide linked industries and institutions mutual benefits, or competitive advantage due to their proximity.[111]

However, production is no longer organized in vertically integrated companies focused solely on home locations. The manufacturing of products has increasingly been fragmented, or decomposed, into discrete phases in complex global production networks (GPN). Today, many products are being built and assembled from more pieces in more places than ever before. Increasingly, each component becomes a point of competition between firms dispersed throughout the world.

Nonetheless, geography still matters and we have found that specialization is still occurring. However, rather than focusing on entire sectors, we need to refine our thinking and start to analyse specific phases of production in particular industries as the main loci of clustering.[112] There is, consequently, an increased need to analyse manufacturing issues from the perspective of phases of production rather than by sector. However, as mentioned in chapter I, the existing aggregate data is not organized in a way that is appropriate for this analysis.

A. Implications of decomposed production: what does decomposition mean for locations and the State?

As phases of production are located in specific places rather than being generally diffused throughout national economies, we are left with two questions. First, how do these phases take on locations? Second, what are the relative advantages and limitations of excelling in specific phases of production?

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[111] M.E. Porter, "Location, Competition and Economic Development: Local Clusters in a Global Economy," *Economic Development Quarterly* 14, No. 1 (February 2000): 15-34.

[112] D. Breznitz and M. Murphree, *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China* (New Haven: Yale University Press, 2011); D. Breznitz, *Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan and Ireland* (New Haven: Yale University Press, 2007).

With respect to the first of these questions, the decomposition of production is not random in its locational impacts. In a very real sense, the location choice results from a cross between a specific window of opportunity and the interaction of particular government actions. These windows of opportunity arise amid the numerous uncontrollable externalities of an increasingly international economy. As a result, these opportunities provide specific advantages for a state to develop.

The State plays a key role in the initial specialization of its IT industry by making essential decisions.[113] First, the State must actively engage with industry to solve the fundamental market failure in industrial R&D. Otherwise, the inherent characteristics of industrial R&D—its indivisibility and high uncertainties, all of which are accentuated in the case of emerging economies with their lack of technological capabilities and finance—would lead private investors to allocate suboptimal amounts of resources to research. Second, State action is also of crucial importance because the innovation process is an inherently collective endeavuor. Thus, innovation is iterative and cooperative in nature; therefore, there is a significant role for public actors in facilitating, enhancing and maintaining innovative activities. Third, the State must actively link the local industry with global markets, both financial and product. Lastly, in each specific industrial sector, the State and industry must be able to manage constant change. State actions and policies that prove successful in the early phases of development might prove harmful in later phases. Specifically, the development agencies should be able to manage the political reality of their own diminishing importance as the industry grows.[114]

Consequently, different countries can achieve rapid and sustainable growth by focusing their innovational activities on particular phases of production and thereby supply unique outputs and services to global markets. Thus, there are different paths to success as a product of unique phase specialization and varied nation policy. Historically we have seen several distinctive examples of such success:

- Israel—a supplier of new technologies
- Finland—success based upon niche concentration
- Ireland—success in low to mid-level activities and products
- Denmark—niche value-added suppliers
- Taiwan Province—original equipment manufacturer/original design manufacturer (OEM/ODM) capital
- China—the innovative mass-flexible production site of the world

It is important to remember that there is no one "best way" of structuring the State to succeed in these tasks. There is no singular structural form, or modes of State-industry embeddedness, to which all successful countries must adhere.

[113] Breznitz (2007).

[114] Ibid.

A State and industry can develop institutionalized mechanisms in many different ways to mediate the relationship between State and national industries: guiding the flow of personnel and information, dictating State approaches to technological and sectoral control and targeting, and determining the linkages of local firms and markets with their global counterparts. States and industry can successfully co-evolve in different ways, and hence, this process of co-evolution is at least as important as the final structural result. Each such mode and process leads to a different industrial system with diverse strengths, weaknesses and relationships with the global markets.[115]

The choices available to the State can be conceptualized along two orthogonal axes. At one end of the first axis, measuring control, are attempts by the State to gain maximum control over development and direct industrial R&D efforts, from basic research to specific products. At the other end of this axis, the State limits itself to incentivizing companies to maximize certain activities, such as product R&D, without targeting any specific sectors or technologies. State decisions on the degree to which it should target sectors and technologies can be conceptualized on a second axis. At one end are States that formulate policies down to the level of defining specific generic products and technologies. At the other are States that see their role mainly as assisting in the realization of decisions made by private firms. In between are States that target specific sectors—for example, software—but do not attempt to target specific technologies or define future products.

For two very different successful examples, we can look at Taiwan Province and Israel. On the one hand, there is Taiwan Province, where the State has been targeting specific technologies and products, authorizing and financing its public research institutions to develop them to the state of working product prototypes, and then either deliver the result to the industry or spin off the research teams as companies to commercialize the results. On the other hand, there is Israel, with a development agency that defined its role as fixing the market failures associated with industrial R&D and maximizing product R&D activities, employing an array of neutral horizontal technology policies.[116] Israel implemented a policy of giving R&D grants for product ideas developed by private companies and entrepreneurs in every industrial branch, helping companies at all phases of development.

B. The different phases of production

Looking at GPNs, we can define four broad roles or phases, in which we can empirically locate different places. For convenience, we present these phases in reverse order, because production, the final phase, is the most concrete.[117]

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[115] Ibid.

[116] M. Teubal, M. "A Catalytic and Evolutionary Approach to Horizontal Technology Policies (HTPs)," *Research Policy* 25 (1997): 1161-1188.

[117] J. Zysman and D. Breznitz, "Double Bind: Governing the Economy in an ICT Era ," *Governance* 25, No. 1 (2011): 129-150.

First, the most basic role in terms of capacities and competencies is production and assembly. In these phases, whether in services or manufacturing, the focus of the activities is producing a product that was fully defined elsewhere, often assembling high-value components that were manufactured/produced elsewhere. Some might view this phase as utterly commoditized, relying solely on cheap labour. To a certain degree, they are correct. However, some highly defensible strategies employed at this phase go beyond the use of cheap unskilled labour. For example, many view South China, particularly the Pearl River Delta area adjunct to Hong Kong, as the optimal location for this faceless and brandless manufacturing service and argue that this is exactly its Achilles' heel; The region's success rests on particular capacities, which are distinctive advantages to succeed in this particular and rather difficult phase. The region occupies a distinctive place in the global production system.[118]

Consider that, in order to truly excel at the production and assembly phase, companies must be able to produce, within a few short weeks, a broad range of extremely sophisticated products, such as iPhones and electronic book readers, or, in the case of software, to supply a working corporate-scale software system to spec. Furthermore, these companies must be able to ramp production up to millions of units within a couple of weeks or fully abort it, at a moment's notice, and still somehow remain profitable on extremely low margins. Accordingly, as we have shown elsewhere, China's competitive advantage does not rely on sweatshops employing a few thousand workers in inhumane conditions, but on the full mastery of flexible mass-production: the ability to orchestrate production of dozens of different products, at the same location, using millions of workers and engineers that needs to be able to move from one product line to the next without missing a beat. This is a feat that most, if not all, American and European companies are incapable of performing. The same goes for either software development or back-office service delivery. The ability to offer semi-skilled workers, mid-level programmers and a few English-speaking back-office services personnel comprises one set of capacities and competencies. But the ability to manage project teams that can grow to a few hundred if not thousands within several weeks and still deliver the same consistency of product, on time, within budget comprises a completely different set of capabilities. The number of countries with companies that can deliver world-class production and assembly-phase competencies is lower than a dozen; China and India lead the way, the first in manufacturing and second in services.

Second, before production is the phase of design, prototype development and production engineering. Design and production engineering companies take product concepts, which were only partly defined by its customers, and realize them, using a variety of production and assembly supplies and subsuppliers. Apart from design competencies, the design and delivery (production engineering) companies also bring to the table the capacity to create a working product or a system from of the large number of components and subsystems produced by many different and constantly changing companies. Many modern electronic

[118] Breznitz and Murphree (2011).

or software products contain multiple, often thousands of, different components and subsystems, and the ability to make them work together and fit within the ever-shrinking confines of the latest gadget gives the design and delivery companies significant competitive advantages. Taiwan Province is widely viewed as the locale that has mastered this phase of production. However, looking at different industries, such as the life sciences, we should quickly realize that even countries such as Denmark and Singapore have become specialized locations for design, prototype development and production engineering.

Third, and not exactly in sequence, is the phase of second-generation product and component innovation. This phase, wrongly seen by some as being merely one of "fast following" or "incremental" innovation, is often the unsung (and sometime despised) hero of economic growth.[119] A fascination with novelty, often generated in Silicon Valley, obscures the importance of this function. Firms working at this phase specialize in how to make existing products and technologies more reliable, more appealing to wider crowds of users, and, last but not least, better.

Accordingly, one of two modes of operation is usually followed in this phase of second-generation product and component innovations. First, working within the confines of established products and markets, companies improve, expand and often redefine these products.[120] The consumer version of the videocassette recorder (VCR), for example, was based on a professional video recorder and player used industrially. Moore's law, the steady increase in computing power, which has been the basis for much of the ICT revolution, is a perfect abstraction of second-generation innovation that has been transforming the way we work, play, think and communicate for the past fifty-five years.[121] Moore's law points to the steady doubling of the number of transistors placed on integrated circuits. Consequently, every two years or so, the possibilities and capabilities of electronic devices dramatically increase.

The second-generation innovation in final products often rests on innovation in the underlying components and constituent elements of products—that is, integrating advances in science and technology. This might be innovation in screen technology or microprocessor design or production technology in semiconductors. Each module, each unbundled process, is a target for innovation. Science-based engineering schools, such as Berkeley, Stanford, MIT and the Georgia Institute of Technology, partner with companies that often "buy" their innovations in this manner. One mechanism for such investment is in advanced engineering communities and the appropriate institutions to link them with the private market.

[119] N. Rosenberg and L.E. Birdzell Jr., *How the West Grew Rich: The Economic Transformation of the Industrial World* (New York: Basic Books, 1986).

[120] An example of such strategy aimed at the top end of the market is Toyota's redefinition of a 140 year old product—the commercially produced car—and creating the hybrid powered cars with the Prius project. However, such strategy can also be aimed at the low-end of the market, for example the US$ 100 laptop project aims to create a simplified, much more reliable version of an extremely well defined product—notebook computers—so some of the poorer people in the world living under severe conditions can afford to use it.

[121] G.E. Moore, "Cramming More Components onto Integrated Circuits," *Electronics* 38, No. 8 (1965): 114-117.

The fourth, and most dramatic, phase, associated in the popular mind with innovation and Silicon Valley, is fundamentally novel product creation, which often results in the creation of entire markets and new industries. This phase has several variations. One of the Silicon Valley variations is the entrepreneurial company driving change. Cisco with the Internet router, Intel with the integrated circuit and the microprocessor, and Apple with the Apple 1 and the iPod represent firms that created components and products that have redefined entire industries. A second variation involves fundamental systems innovation, here called system-driven. Innovations in the delivery of electricity were often made by individual entrepreneurs, such as Thomas Edison, who were able to imagine and develop an entire system. Now, such radical system shifts are more complicated. Huberty and Zysman have argued that the energy systems must shift from a high-carbon, low-efficiency energy system to a low-carbon, high-efficiency alternative. Success requires the development, commercialization and diffusion of many "suites" of complementary energy technologies throughout society.[122] The agent of innovation in these cases is often a government. The French creation of a nuclear-based system of providing electricity or the Danish leadership in wind generation represent systemic shifts that involved both government conception of a "new system" and various forms of technological innovation.

Both variations require a distinct set of competencies, beginning with conception, definition and design. The ability to come up with a new product, or a new system, is very different from the ability to define it and design it. Such a competency to conceive fundamentally new products and systems should be distinguished from production engineering.

As these examples make clear, this phase is the most collective and where the famed "communities of innovation" are the most crucial.[123] Nonetheless, as the numerous failed attempts to create new "Silicon Valleys" attest, policies that aim to achieve the capacities and competencies needed to excel in the novel product creation phase are the hardest to pull off.[124]

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[122] M. Huberty and J. Zysman, "An Energy System Transformation: Framing Research Choices for the Climate Challenge," *Research Policy* 39, No. 8 (October 2010): 1027-1029.

[123] W.W. Powell, K.W. Koput and L. Smith-Doerr, "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology," *Administrative Science Quarterly* 41, No. 1 (1996): 61-89; C. Antonelli, "Collective Knowledge Communication and Innovation: The Evidence of Technological Districts," *Regional Studies* 34, No. 6 (2000): p. 535-547; D. Breznitz, "Collaborative Public Space in a National Innovation System: A Case Study of the Israeli Military's Impact on the Software Industry," *Industry and Innovation* 12, No. 1 (2005): p. 31-64; S.M. Breznitz, R. O'Shea and T. Alan, "The Role of Research Universities in the Development of Regional Bioclusters: A Study of MIT and Yale Commercialization Strategies," *Journal of Product Innovation Management* 25, Issue 2 (2008): p. 129-142; P. Cooke and K. Morgan, *The Associational Economy* (New York: Oxford University Press, 1998); D. Keeble et al., "Collective Learning Processes, Networking and Institutional Thickness in the Cambridge Region," *Regional Studies* 33, No. 4 (1999): p. 319-332; R.K. Lester and M.J. Piore, *Innovation—The Missing Dimension* (Cambridge: Harvard University Press, 2004); K. Morgan, "The Learning Region: Institutions, Innovation and Regional Renewal," *Regional Studies* 31, No. 5 (1997): p. 491-503.

[124] N.C. Nielsen and M.C. Nielsen, "Spoken-About Knowledge: Why It Takes Much More Than Knowledge Management to Manage Knowledge," in How Revolutionary Was the Digital Revolution? National Responses, Market Transitions, and Global Technology in a Digital Era, ed. J. Zysman and A. Newman (Stanford: Stanford Business Press, 2006; T. Schultze-Cleven, "The Learning Organization: A Research 79 Note on Organizational Change in Europe: National Models or the Diffusion of a New 'One Best Way'?'" by E. Lorenz and A. Valeyre, in *How Revolutionary Was the Digital Revolution? National Responses, Market Transitions, and Global Technology in a Digital Era*, ed. J. Zysman and A. Newman (Stanford: Stanford Business Press, 2006).

C. Moving towards the sweet spot: different challenges for different paths

In a world of commodities, the challenge is to find the sweet spot in the value network. It is not a matter of which sector you are in, but where you are located in the value network.[125] As a result, places, not just products, increasingly risk commoditization as well.[126] This raises two questions: How do States ensure that they are able to offer something distinctive and valuable? And what can a State do to become a major manufacturing centre? As we have established previously, a State can only build on its own unique political and industrial legacy.

The window of opportunity necessary for rapid innovation-based development is a unique experience that arises in part as a result of international economics and in part as a result of a state's specific legacy. States must capitalize on this window with strategic involvement, and they must comprehend how industrial R&D and dynamic economic capabilities are created, improved and maintained. Moreover, it is essential that States understand how relationships between local industry and the global industrial and financial markets develop and operate. Consequently, States must develop some key competencies, detailed below:

- Product creation—conception, definition and design.
- Production engineering—manufacturing, integration of production activities and logistics.
- Component innovation—integration of scientific and technological advances
- Branding—differentiation and value creation through branding and marketing
- Building bodies of knowledge embedded in infrastructures and business systems and developing the competence to use them.

Product creation

Product creation comprises a set of competencies that begin with conception, definition and design. As mentioned earlier, the ability to come up with a new product is different from the ability to define and design it. This competency should be distinguished from production engineering. Bang and Olufsen, the Danish high-end consumer electronics firm, has, in our view, defined many products, often doing the careful design and engineering in-house. It has often taken an existing product, for example, a CD player, and turned it into an *objet d'art*. IDEO, by contrast, is a company that sells aspects of this capacity as a service to other firms, helping them to define products and designs. For example, it designed the first mouse for the Apple Macintosh and Lisa. Or consider Motorola. The advent of digital technology has allowed many people to forget

[125] Zysman and Breznitz (2011).

[126] J. Zysman, N.C. Nielsen, D. Breznitz and D. Wong, "Building on the Past, Imagining the Future: Competency-Based Growth Strategies in a Global Digital Age," Working Paper 181, BRIE, October 2007.

that, not so long ago, this American company was world famous, thanks to its ability to come up with many new analog mobile communication devices, from the first commercially successful pagers to the early, analogue cell phones.

This activity—imagining concepts and translating that imagination into an operational process or product—often requires knowledge and skills that cannot be codified and moved around easily. Hence those skills are a magnet for activities. At the same time, if such skills are lost, then a significant part of a region's more general attraction goes with them. Accordingly, developing a distinctive advantage and training in industrial design in general and in particular segments can generate a "skill community" that attracts development and production activities to a locale. After a region has successfully invested in, or attracted, skilled workers in this area of production design, it can take its place in a GPN value network where high value is generated.

The production of mobile phones provides some insight into this dynamic. Mobile phones are boxes made of plastic and metal boxes that have electronic components enabling access to services and features. The bundling of these services and features is often conceived of at the product definition and design level. Now mobile phones have global positioning system (GPS) navigation, the ability to play digital music, e-cash and banking functions, pedometers, and Internet browsers that permit, among other things, access to television programmes. It is no longer clear what exactly a mobile phone is anymore. Rather, it is a box with abilities that have been conceived of and bundled by a concept team, and this is where the value is created. Take the smartphone. Engineers at Apple, Microsoft and Google create new operating systems for smartphones. Then HTC, a Taiwanese firm, based on that work, creates unique and differentiated functions, and create a market demand for HTC phones in particular, not merely a nonspecific smartphone.[127] If regions are able to draw in or create those businesses, they defend the value created.

Production engineering

This domain includes manufacturing, the integration of production activities, distribution and logistics. There is clearly not a single expertise in this domain and companies and places do differentiate within it. The lean production model of Japan and the volume models of Korea differ from the high-quality, low-volume model used in Denmark. Much of the way high value is created in the modularization age is through coordination. As business activities break into modularized elements, their multiple subcomponents risk floating away. Those disparate bits might (or might not) create high value, but they hold little market value unless they are recombined for final delivery. Obviously, the traditional vertically integrated company engaged in such coordination under one corporate roof and sometimes in one locale. It was relatively easy, as everything was internal to one corporation and often collocated in one region. However, as businesses

[127] Breznitz (2007).

devolve and modularize, a part of the business has to coordinate those modules in order to ensure competitive success. Dell and Compaq (now part of HP PC and laptop division) have created value and advantage by coordinating sales and production for what amounts to commodity boxes, though in different ways. The product designs, let alone the constituent elements of the notebook computers, have been largely outsourced and modularized and many business processes are unbundled offshore. Most of the two companies' business activities have been modularized and have often been turned into commodities, and now they produce almost no part of the product sold to the customer under their name, so in many respects they are little more than a brand label on a shipping container. In a sense, the firms are master coordinators of modules that circulate in the global economy, with expert competency in creating high value from the management of disparate low-value modules. Recently they made a new strategic move by taking coordination a step further by acquiring high-end system OEMs—Voodoo in the case of HP and Alienware in the case of Dell—which enables them to differentiate the products through performance and design.

Other companies opt not to deal with the final users but to sell coordination as their fundamental business, whether as producers of specific products such as notebook computers, of which the most noted example is Quanta, or as general contract manufacturers of diverse products, such as Solectron or Flextronics.

Component innovation

The third competency domain consists of integrating scientific and technological advances, which might mean innovation in screen technology or microprocessor design or the production technology for semiconductors. Each module, each unbundled process, is a target for innovation.[128] R&D labs call on much of the high-end technical engineering skills that make our previous example of mobile phones possible. Science-based engineering schools such as Berkeley, Stanford, MIT and Georgia Institute of Technology link to companies that often "buy" their innovation in this manner. One mechanism for such investment is in advanced engineering communities and the appropriate institutions to link them to the private market.

Enormous private and public attention is focused on this domain. Indeed, the recent interest in venture capital, industry university relations and many aspects of the open innovation discussion are all elements of this domain. Silicon Valley is evidently a "place" with this focus and competency. Its success stories include Intel, National Semiconductor, Maxtor and Sun—but it is not alone. Israel has made a basic technology bet in its national development strategy focusing on this competency; similarly San Diego is engaging in a conscious effort to create such a competency.

[128] Ibid.

Branding

Branding and marketing are a fourth competency domain. But branding is no longer an afterthought. It is not separable from strategy, positioning and investments in skills and technology. A company must be able to deliver the brand as promised and hence must be organized around realizing that promise. Through creative branding, businesses can define their offerings in ways that position them in large markets with few competitors—called blue oceans of value—rather than being stuck in the waters of more established market segments with highly contested and possibly frenzied competition. They try to escape the commoditization trap.[129] Southwest Airlines entered the market with an innovative product, offering low-cost basic service, and built a national network focused on making good on that offer. Now, the Virgin America airline is trying to differentiate itself in the low-cost segment of air travel by offering substantially different services in the cabin, for example, including Internet access on specific routes.

The screwtop wine industry is in a different market to that of the sophisticated wines of France that carry the *Appellation d'Origine Contrôlée* (AOC). In addition, just as value is often created in the mind of the final consumer, value is often defined by branding. For instance, Apple Computers introduced the iMac in 1998 not just as a computer with affordable and advanced computing capacities but also as a part of a new lifestyle that takes a creative, humanistic approach to computing. Since then, Apple has associated its brand with outsiderism and a youthful, artistic edge. The key for Apple has not been to associate its brand with products, as it has been traditionally done, but with emotions and a social identity. This strategic marketing and branding saved Apple from near-death ten years ago and allowed it to return to creating high-value products for both the company and the region where it is headquartered, Cupertino in Silicon Valley. BMW is trying to become more than a car by branding itself as "the private independent car company" that produces the "Ultimate Driving Machine."

The full list of competency domains would be quite long, and the ones described here are simply examples. The debate must be about which competencies are central to the ability of firms and regions to adjust and adapt to the fluidly shifting global economy. These particular competencies must, of course, be combined in innovative ways within existing firms or new firms—an entrepreneurial competency.

Building bodies of knowledge

So our fifth competency domain, to truncate a very complex discussion for now, is a set of bodies of knowledge embedded in infrastructures and business systems and the social competence to use them.[130] For example, there is the competency to financing_and launching innovative activity. The American venture capital

[129] K.W. Chan and R. Mauborgne, *Blue Ocean Strategy: How to Create Uncontested Market Space and Make Competition Irrelevant* (Boston: Harvard Business School Press, 2005).

[130] Again our thanks to Jonathan Murray who helped us phrase this particular competency.

system concentrated in a few locations in the United States is a classic instance of a body of competencies that grew up initially and principally through the expansion of IT industries. Likewise, there is the competency to exploit the new possibilities of data and communications technology effectively. That is not just a matter of collections of individual skills but of the IT infrastructure. In the nineteenth century, the critical transport systems in the economy were roads, railroads and the telegraph. In the twenty-first century, the data network system, in all its various forms, will be critical for the business experimentation central to generating competitive advantage. Having the IT infrastructure without the competency to use it, and to find new uses for it, is like having a new computer collecting dust in a store room. IT requires broadly based competencies in computer skills, not only to build the new tools as products and services for sale but to effectively use them and imagine their implications for all the sectors that use them.

A critical issue is whether the development of one set of capacities required for one role in the value network interferes with or supports the development of capacities for a different role. Can two different sets of competencies coexist in a particular place? Or will they interfere with each other? Rephrased, the proposition is that each set of competencies and capacities requires a distinct set of institutional foundations, so the question becomes whether those institutions can coexist in the same place and within the same national rules. Some argue that size is the definitive factor and that only large countries can have regions that specialize in different phases. This is only a partial answer, if it is an answer at all. We do not view the production roles or phases as exclusive. Furthermore, there is always a need to have certain competencies from other phases in order to excel in innovating in a specific one. Therefore, locales not only can but must retain competencies from several phases in order to fully master one. The competencies principally required for a particular role, say, product design, do not stand alone. They require at least access to complementary capacities—and access to those complementary capacities demands adequate local resources to absorb knowledge and coordinate with others. Hence, if Israel now appears to be an embodiment of focus on novel product creation, a deeper analysis reveals that it also excels at many of the activities suited to second-generation and component innovations. Indeed, a more prudent long-term strategy for any region is to specialize in one phase but retain competencies in another to allow it to coordinate and collaborate with other places and, when needed, transform its core activities as the markets, industries and technologies in which it specializes change over time.

D. Conclusion: different paths to success

We have seen a variety of examples of diversified and highly successful development of countries that not long ago were either very poor or faced existential economic crises. These are the lessons that policymakers in the less developed countries of Latin American need to ponder, especially in comparison to the difficulties faced by economically promising countries in the region. For example, what institutional and political constraints have prevented Chile from following in the footsteps of Denmark or Finland and building on its great strengths in high-end agriculture and resource extraction to become a global leader and a truly rich society? Or, following a different model, why have Taiwan Province and, later, China have become rich while Mexico, which enjoys significant geographical advantages, failed to use utilize the same strategy?

The answer is that Denmark, Finland, Ireland, Israel, Taiwan Province and China have each, benefiting from unique windows of opportunity, successfully developed in different ways. Furthermore, unique State interactions have laid the groundwork for their successful development. In each example, varying degrees and structures of embeddedness have determined the relationship between industry and the State and the degree of control of the latter over the former. The unique solutions have capitalized upon the individual industrial, social and political legacies of each State. Yet each unique successful trajectory comes with its own new challenges as well.

In Denmark, opportunity presented itself with the economic crisis of the 1970-1980s. Escalating costs and the breakdown of the old state welfare system coupled with a near-systemic collapse of small and medium enterprises (SMEs) had resulted in unemployment of nearly 10 per cent. In 1982 Denmark was considering a bailout by the International Monetary Fund. However, today Denmark is one of the richest and most successful Nordic countries. Denmark is home to a multitude of high-innovation SMEs in agriculture, traditional and high-tech industries. Through intensive supply-side investment in vocational education and R&D, Denmark developed an increasingly flexible welfare state with extensive training in flexible labour. Denmark developed success as both a supplier of niche-market ICT and traditional high-value-added niches. However, Danish firms are often subsidiaries within the global market. In addition, while Danish SMEs have been successful they have had difficulty in scaling up industries. Denmark must also address its lagging research capabilities and lack of innovational capacity.

Finland is another excellent example of a small, Nordic country that followed a unique and highly successful path to development. After the collapse of the Soviet Union in 1991, the Finnish economy suffered greatly. During the 1990s, Finland faced a severe economic crisis in which manufacturing output had fallen by 15 per cent and unemployment peaked at 17 per cent. However, Finland is now considered one of the most successful and innovative countries in the world in both IT and traditional industries. Nokia in particular is recognized as a world leader in mobile telephony and remains a significant driver of this growing industry. Arguably, Finland's ICT successes have centred on this one company. However, Finnish success has extended to the revitalization and revamping of traditional industries as well. The country's unique path has resulted in unique challenges as well. Despite the success of Nokia as a "national flag company" in a traditional sense, Finnish SMEs have struggled in their attempts to globalize both internally and externally. Beyond Nokia, there are few “household” names, even if the Angry Birds game from Rovio has become the favorite pastime of many smartphone owners.

Aside from the Nordic examples, Israel has faced many challenges and seized upon a unique window of opportunity for development. As late as 1968, the entire industrial sector had a total of 886 R&D workers with an academic education, and between 1978 and 1986, Israel suffered from inflation that topped 486.23 per cent. The situation has been completely reversed. Israel has the largest number of IT firms listed on the NASDAQ, after the United States and Canada. In 2010, Israeli IT exports were valued at US$ 13 billion and was responsible for 71 per cent of industrial exports and 70 per cent of the country’s GDP growth. The rise of science-based industry in Israel is largely the product of pioneering use of horizontal technology policies by the State, which is taking an active role in linking Israeli high-technology firms and global (early one mainly American) financial and product markets. Israel has succeeded as a supplier of new technologies and products, including both hardware and software. With Israel’s success come additional challenges. The close links between Israeli firms and the United States financial and consumer markets led whole industries to migrate to the United States. Sustaining this rapid success will prove an ongoing challenge for Israel. As economic inequality continues to develop in Israel, Israel must continue to follow its current ICT focus.

Ireland has historically been nearly synonymous with economic hardship. Prolonged economic challenges as far back as the 1840s have resulted in repeated waves of massive emigration. In 2007, Ireland was the world’s second-largest exporter of software. Ireland’s success has been a result of targeted R&D in tradable services, with software as the focus. Ireland’s business environment was crafted to encourage the entrance of multinational corporations (MNCs), which allowed Ireland to achieve economic growth, particularly in IT. Ireland’s success was based on low to mid-level activities and products, particularly software. The country continues to face its share of challenges. Despite its success in software, Ireland failed to achieve the same results in its attempt to focus on hardware. Moderate R&D and innovation capabilities coupled with stagnation in technological entrepreneurship have prevented stability in Ireland’s development.

Taiwan Province had previously suffered from an excessively rigid economy, in which private industry refused to invest in new industrial domains such as semiconductors, thus many traditional industries stagnated. State policies of funding public research institutions created large production competencies within the targeted sectors, namely electronics and semiconductors. The Taiwanese government’s targeted control and function as the “R&D agent” rapidly developed its semiconductor industry. As early as 2005, the Taiwanese semiconductor industry realized revenue of US$ 21.4 billion and was recognized as the world’s second-largest such producer. Likewise, the State encouraged the entrance of MNCs and then maintained a “hands on” approach of carefully protecting and advancing Taiwanese industrial interests. Taiwan Province has now become the world’s leading OEM/ODM industry supplier of components and second-generation innovation. As a result, Taiwanese ICT hardware has been a tremendous success. However, the tight controls of the Taiwanese institutional system inhibit novel product innovation, which will become an increasing challenge with the maturation of the ICT industry.

Finally, China is the first case of a manufacturing-based economic miracle to occur in the new world of decomposed production. China has taken advantage of the opportunities offered by fragmented production. After entering the IT industry's GPNs at the simplest point—assembly—China developed a massive collection of capabilities in production, logistics, incremental improvement and second-generation innovation. Because of the deep crisis facing China in 1978, it is an open question whether China's piecemeal approach to reform—groping for stones to cross the river—would have been successful, or even sufficient, without the global decomposition of production. Without the advent of spatially fragmented production, China would have had to develop missing capabilities and invest on a much larger scale than either its economic and financial resources would have permitted. The success of China is a clear example that Western obsessions with novel product innovations are not the only path to economic growth.

Emerging economies will do well to carefully analyse the entry points open to them and devise their policies to fit the phases of production (and, accordingly, innovation) at which they excel. Policy deliberation and experimentation by local officials is critical, because economic development is, above all, a contextual process.[131] Their choices will have long-term consequences so they need to be especially attentive in their deliberation and decision making.

[131] D. Rodrik, *One Economics, Many Recipes: Globalization, Institutions, and Economic Growth* (Princeton: Princeton University Press, 2007).

V. Manufacturing metropolises: design, fabrication and service

Paul Wright[132]

A. Introduction

Where and how goods are produced has been transformed by a broad variety of technological developments. This chapter looks at the transformation from the perspective of information technology (IT) tools. It considers how IT tools support, promote and accelerate the connections across the production phases of twenty-first century manufacturing:[133] ideation, design, prototyping, fabrication, supply chains, sustainability and engineering services. IT tools have changed manufacturing, with consequences for the location of production activities. Innovation, as Breznitz argues in this volume and elsewhere, comes in many forms and at each stage of manufacturing.[134] The decomposition of production, as noted in earlier chapters, makes possible and is generated by strategies by competitors from diverse places at each point along the manufacturing and services production networks continuum. A century ago, the production strategies of automobile producers in the United Kingdom and the United States had sharp differences. As a result, the United States focused on production efficiency, typified by Henry Ford, whereas the United Kingdom focused on customization and hand finishing, typified by Rolls-Royce.[135] Now, as noted by Breznitz, places have increasingly focused on phases of production, on particular stages of manufacturing. The particular location in the supply networks is a function of a set of policy choices, as outlined by Breznitz. The UNIDO perspective and its analytical approach should be to align the resources of a particular country with a particular niche in twenty-first-century manufacturing. Places do not need to mimic Silicon Valley but, rather, must create their own foundations for their own innovation strategies in the new integrated production systems.[136] They must, to quote Zysman et al., build on their past while imagining their future.[137]

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[133] Beginning from very different points of analysis, Paul Wright and Dan Breznitz identify nearly identical phases in the Manufacturing Continuum and address them with parallel concepts. However, for this report we do not attempt to reconcile their vocabulary and conceptions.

[134] D. Breznitz, *Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan and Ireland* (New Haven: Yale University Press, 2007).

[135] N. Rosenberg, *Perspectives on Technology* (Cambridge: Cambridge University Press, 1976).

[136] An informal personal comment: Writing as the director of the Center for Information Technology Research in the Interest of Society (CITRIS), we entertain many international trade groups searching for the "magic" of the greater Silicon Valley area. This is a worthy endeavour of course. But not necessarily to be directly copied—rather the best outcome is to see how another geographical region can partner (formally or opportunistically) with the Valley and other international metropolises.

[137] J. Zysman, N.C. Nielsen, D. Breznitz and D. Wong, "Building on the Past, Imagining the Future: Competency-Based Growth Strategies in a Global Digital Age," BRIE Working Paper 181, 2007.

IT is the key enabler common across the twenty-first-century manufacturing continuum, or stages of production, and across all places and firms participating in global supply networks and markets. Consider the continuum of twenty-first-century manufacturing: computer aided design (CAD), virtual prototyping, planning, robotics, automation, quality control, scheduling, supply chain management and after-sales service networks. All the elements along this continuum are powered by IT or the digital revolution. Even topics such as automated visual inspection of components, micro/nano measurement sensors, or layered manufacturing (which on the surface might seem like a much better camera, chemical sensor, or fascinating physical process) are still heavily dependent on faster computer chips, software, wireless technologies and high-speed networking. Newer developments such as cloud computing and large-scale data analytics further support an evolution in manufacturing.[138]

B. Ideation

"Designed by Apple in California; Assembled in China"

back face of an iPhone

The first stage in the twenty-first century manufacturing continuum is ideation. Today it is possible for a lone designer sitting in seclusion to "design something new" and, with good Internet access, go to a rapid-prototyping bureau to obtain a physical prototype to hold and examine. Moreover, the original design and a photograph of its prototype can be posted online, on websites such as Thingiverse[139]—a fabrication community aimed at sharing and collaborating on digital designs. Thingiverse also provides a searchable library of digital designs free for users to download and fabricate themselves. The result is that an online community, or social network, of designers and prototyping services is expanding quickly. Furthermore, with good Internet connections, any English speaker from any country can participate, given the now-inexpensive design tools and rapid prototyping services described in the next two sections.

This is an exciting vision: global communities of inventors who can make their dreams come to life in prototype form. However, scaling an original design or prototype to large consumer markets and profits involves many steps and many decisions that affect the manufacturing process. Start with the basics, the sort of question that confronted Henry Ford and Rolls-Royce in the auto industry a century ago. Is this a product destined for large consumer markets or small boutique consumption? The role of trial marketing, focus-group testing, pricing

[138] For a treatment of cloud computing more generally, see: M. Armbrust, A. Fox, R. Griffith, A.D. Joseph, R.H. Katz, A. Konwinski, G. Lee, D.A. Patterson, A. Rabkin, I. Stoica and M. Zaharia, "Above the Clouds: A Berkeley View of Cloud Computing," Electrical Engineering and Computer Sciences Department, University of California, Berkeley, Technical Report UCB/EECS-2009-28, 2009; K. Kushida, J. Murray and J. Zysman, "The Gathering Storm: Analyzing the Cloud Computing Ecosystem and Implications for Public Policy," *Communications and Strategies* 85 (2012).

[139] Thingiverse, "Digital Designs for Real, Physical Objects. A Universe of Things!" Makerbot Industries, 2012, www.thingiverse.com.

and patent protection all come into play even before a serious working prototype should be shown to investors. And who are the investors in the project? Government funding through business development grants; angel investors; formal venture capital firms; banks; friends and family; or the actual designer who is maintaining his or her day job elsewhere? Of course, the more complex the product in terms of its physical hardware, electronics, chemistry, biology, or long-term software development, the more costly the process and the lead time to a completed product. As a consequence, despite the power of the emerging design tools, the lone designer or the new international entrant will still face significant challenges.

Silicon Valley, with its distinct culture, bred Apple, Google, Facebook and Twitter, and Intel and HP before them, and is the epitome of innovation in the ideation stage of manufacturing, as Breznitz argues. The innovative designer and the ambitious entrepreneur were embedded in a community with legal, financial and technical tools to develop and deploy their ideas. Indeed, the Palo Alto-based product-design firm IDEO[140] is synonymous with ideation. IDEO is focused on conceiving and designing products. Silicon Valley grew up with a "Wild West" mentality. New planar transistor companies such as Intel, National Semiconductor and AMD were established in the spirit of the 1960s radical spirit, far from the more conservative corporate culture typical of more established firms of the East Coast of the United States. This spirit of the 1960s spilled over into the computer culture that developed Apple, the surrounding culture of Berkeley and Stanford, and the attraction to California of alternative lifestyles in fashion and mores.

But, as we know, much more than an attitude or culture was involved. Silicon Valley is rooted in the university research community of Berkeley, Stanford and the University of California at San Francisco. It developed financial and legal institutions of venture capital and remains the global centre for venture finance. A significant chunk of all United States venture capital funding goes to support work in the coastal strip between Silicon Valley and Los Angeles/San Diego.

C. Engineering design and its impact on prototyping and full production

> "The silence is unsettling, as is the sight of half-assembled cars gliding about on robotic transporters that move as if they had minds of their own. The scene of this industrial serenity is Porsche's assembly line in Leipzig, Germany."
>
> *The Economist,* February 3, 2011, pp. 81-83

We now move one step along the continuum to the painstaking and detailed engineering design work of large and small, simple and complex, societal artifacts. Beginning with the largest scale or most complex, the United States, Japan,

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[140] IDEO, "We Are a Global Design Company. We Make Impact Through Design," IDEO, 2012, www.ideo.com.

the Republic of Korea and the European Union are still home to the leading engineering design and fabrication companies in aerospace, chemicals, machinery, medical equipment and, of course, semiconductors. Kaushal, Mayor and Riedl[141] of Booz & Company, identify these categories in an important review.[142] They write that the sheer scale, complexity and knowledge intensity of semiconductors and aerospace design (for example) warrant complex engineering design tools and visualization systems that allow virtual assembly before costly physical assembly. By using such tools, large aircraft such as the Boeing 777 were assembled in electronic virtual form long before the more costly production and assembly lines were laid out. So was the Porsche production line referred to in the above quotation. Today, these computer-based visualization tools are almost mandatory.[143] Not only do they save time and money in designing the future factory, but they also allow real-time simulations and "what-if" scenario planning of different production schedules. In addition to these complexities of design, it is pointed out that aerospace manufacturing, in particular, requires uniquely qualified labour, substantial support from corporate R&D, and proprietary technology investments that are often tied to national security and regulatory requirements.

However, "sectors on the edge" (a phrase coined by Kaushal and colleagues)[144] consist of a slightly less sophisticated second group of design and manufacturing environments and they are increasingly accessible to low-cost design and manufacturing in many countries and companies around the world. This category of products includes electrical equipment and components, fabricated metal products, automotive vehicle subparts, other transportation equipment, final assembly of automobiles, and printing services. IT networks from designers to fabricators and, in reverse, physical supply chains from lower-cost manufacturing countries to global markets are, therefore, in common usage.

A developing country that wishes to enter or expand its economic role in the global community should focus on such linkages from the engineering design companies in the United States, Japan, the Repubic of Korea and the European Union to skilled fabricators in the local region. Such a focus has already supported the rapid expansion of global trade in these categories of engineering "sectors on the edge." For example, it has created a global collaboration supporting a truly massive market of consumer items. Toys, hardware and so forth are designed in the United States, Japan, the Republic of Korea and the European Union and made into products in East Asia by plastic injection molding shops (in Taiwan Province especially) and printed circuit board manufacturers and final-product assembly houses in China, such as Elec & Eltek and Foxconn, respectively.

[141] A. Kaushal, T. Mayor and P. Riedl, "Manufacturing's Wake-Up Call," *Booz and Company* 64 (2011), Reprint 11306.

[142] Ibid.

[143] Fiat, Fiat Group Automobiles, P.IVA 07973780013, 2012, www.fiat.com/cgi-bin/pbrand.dll/FIAT_COM/home/.

[144] Kaushal, Mayor and Riedl (2011).

A variety of engineering design tools (CAD tools) will support this global enterprise. At the desktop PC level, constraint-based design and parametric modeling tools are now commonplace.[145] Design engineers can create a new object, scale, rotate, view, assemble to other parts and link to downstream manufacturing processes. Training and practice are needed to arrive at a complete and manufacturable object, but even for new designers simple "art-to-part" design and fabrication tools are available.[146] This design software is available globally and relatively inexpensively, and the CAD system can be downloaded—in some cases, at no cost. In a similar vein, the universities and trade schools of most developed countries offer "student editions" of most of today's commercial CAD/CAM [computer-aided manufacturing] systems so that relatively inexpensive design training can be performed widely. These CAD tools should be purchased in developing countries that wish to gain entry to the above-mentioned "sectors on the edge." For more complex designs, say, in aerospace, the fully integrated packages of design tools allow cross-platform and cross-company consistency, and they are consequently more expensive to buy, run and train for. Developed countries and firms with large budgets for purchase, training and integration are the environments most likely to obtain and make use of these systems. Design sharing of partially created objects, developed by the author and colleagues,[147] and newer visualization tools allow full integration of product data management and support services (imaginestics.com). Proof by prototyping is often a part of this validation of capability procedure and leads into the sharing of design repositories[148] in cloud computing environments and the ability for any country or firm in the world to bid on subcontracts provided that they have been validated and authenticated by the first-tier fabricator.

D. Prototyping, additive manufacturing and mass customization: optimism and caution

Originally developed in 1987 as a specialty prototyping capability, additive manufacturing is now a billion-dollar industry with an increasing trend toward mainstream production and manufacturing implementation. The price of additive manufacturing systems continues to fall while the production capabilities advance. Build accuracies continue to improve in tandem with an increasingly functional variety of material selections. These improvements drive the implementation of additive manufacturing from prototyping to the final manufacture of goods and—arguably—drive portions of production to additive manufacturing.

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[145] J.S. Shah and M. Mäntylä, *Parametric and Feature-Based CAD/CAM: Concepts, Techniques, and Applications* (New York: Wiley, 1995).

[146] eMachineShop, "Custom Parts Online," www.emachineshop.com.

[147] S.H. Ahn, B. Bharadwaj, H. Khalid, S.Y. Liou and P.K. Wright, "Web-Based Design and Manufacturing Systems for Automobile Components: Architectures and Usability Studies," *International Journal of Computer Integrated Manufacturing* 15, No. 6 (2002): 555-563.

[148] W. Regli, T. Kim, J. Han, C. Cera and C. Choo, "Multi-Level Modeling and Access Control for Secure Collaborative Design," *Advanced Engineering Informatics* 20, No. 1 (2006): 47-57.

Additive manufacturing provides producers with the ability to offer individually customized goods that are uniquely differentiated from the offerings of their competitors. In a world of commodities, competitive differentiation equates to value. For this reason, additive processes have begun to prove especially successful for mass-customization markets, such as the biomedical industry. The additive manufacture of high-value biomedical goods, such as personalized hearing aids and titanium acetabula cups with individualized orthopedic interfaces for hip replacement, has been very successful.

Beyond the biomedical industry, the future of additive manufacturing looks increasingly bright. These direct digital manufacturing processes have an obvious benefit and attraction in that they permit customers or clients to customize and interact with their purchases. As many of today's goods are initially designed in a digital format, undoubtedly, the success of additive manufacturing is driven by its inherent digital flexibility and seamlessness or ability to transition directly from design to fabrication.

Additive manufacturing's wide spectrum of processes offers something for everyone. The accessibility of additive manufacturing has greatly increased in the past several years. The majority of system producers now offer a full line of production systems, providing manufacturers with systems that are more appropriately suited to user-specific capability and cost requirements. In addition to the selection of professional additive manufacturing systems, several "open source," low-cost alternatives are being developed for and by various do-it-yourself (DIY) communities and universities around the world.[149]

All products produced with additive manufacturing originate as a digital 3D model (typically a CAD or .STL [standard tessellation language] file). This 3D model is then digitally divided into various horizontal layers, as in a stack of pancakes. The additive manufacturing system then deposits and bonds the base layer of media (the exact media and bonding process are determined by the specific additive process selected). Starting from the bottom, products are "added" together, layer by layer, until completion. In contrast to the 1987 version of stereolithography (SLA), current additive manufacturing produces goods in a wide variety of highly functional materials. Although the general process remains similar, materials including stainless steel, titanium alloys, polymers, resins, ceramics and engineering plastics can be used in additive processes today. Understanding the specific capabilities and potential uses of additive manufacturing is facilitated by considering which is the most appropriate among the various specific additive manufacturing processes, detailed below.

Stereolithography (SLA) has continued to evolve to produce highly detailed, highly accurate prototypes from ultraviolet-curable photopolymers and resins. SLA cures media with the use of a high-intensity ultraviolet (UV) light. Today, SLA still provides prototyping capabilities with some of the highest accuracy.

[149] The most notable of these are the RepRap (www.RepRap.org) and MakerBot (www.makerbot.com) systems.

However, because of challenges with biocompatibility and the limited mechanical properties of the photopolymers used by SLA, the "end-use" implementation of the process is limited.

Fused deposition modeling (FDM) was developed in 1988 by Stratasys.[150] FDM provides increasingly robust productions in a variety of thermoplastics, polycarbonates and other engineering plastics, including acrylonitrile butadiene styrene (ABS). The FDM process feeds coiled media through a heated nozzle, which distributes each layer one at a time. FDM has been successfully implemented in numerous industries for prototyping and, because of its mechanical characteristics, has started to find limited use in the production of end-use parts.

Selective laser sintering (SLS) was the first additive process that standardized the use of metal media such as stainless steel and reinforced nylon. The functional characteristics of SLS materials allowed for the increased end-use of fabricated goods. SLS process binds media together with the use of a high-powered laser. Despite apparent advantages of SLS, the porosity of fabricated parts can still present a challenge. Metal SLS parts often struggle to surpass 70 per cent density, which in some cases limits use. Excessive porosity in SLS parts was addressed in 1994 with the joint development of direct metal laser sintering (DMLS) systems by Rapid Product Innovations (RPI) and EOS[151] from Germany. In contrast to SLS, DMLS can produce parts with 95 per cent density, which offers further end-use product potential. However, the remaining porosity continues to limit the application of DMLS in the biomedical and aerospace industries.

In addition to SLS/DMLS, since 1997 Arcam[152] from Sweden has been developing an electron beam melting (EBM) process for use with a variety of metals, including titanium alloys (6-4, 6-4 ELI). Apart from the different binding mechanism, the EBM process is differentiated from SLS/DMLS by its production of 100 per cent dense parts that are entirely compatible with post-fabrication machining. In addition, EBM parts are produced within a vacuum at high temperatures, thereby reducing the risks associated with reactive materials and residual stress in parts. The cost of EBM systems can be prohibitively expensive.

"3D Printing" (3DP), supplied by ZCorp,[153] binds various powdered media, including ceramics, composites, ferrous and nonferrous metals, through the use of a liquid adhesive. 3DP has found great success because of its comparatively low cost and ability to print various ceramics in 24-bit colour. As a result, 3DP is widely used for presentation models and artistic products, less so for functional engineering implementation.

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150 Stratasys, "Stratasys: Make It Real, 2012, www.stratasys.com.

151 EOS, "EOS: e-Manufacturing Solutions," 2012, www.eos.info/en/home.html.

152 Arcam, "Arcam AB. Cad to Metal," 2009, www.arcam.com.

153 Solid Concepts Inc. (2012)., "Z-Corp 3D Color Prints." 2012, http://www.solidconcepts.com/z-corp-3d-color-prints.html?gclid=CKuo3tagiK8CFWc ZQgodsHb-8Q/.

While we remain very optimistic about the long-term application of additive manufacturing, we close this section with some cautionary observations. In the past two decades, the authors and their graduate students have used rapid prototyping by fused deposition modeling on a daily basis to create first prototypes and semistructural parts for research purposes. FDM machines are easy to connect to CAD systems and are easy to set up. A careful student can learn to use the machines in half an hour. However, these machines do not produce structural parts, and the accuracy could not match subtractive processes such as machining until recently. Finally, the obtained prototype is expensive: if there is a need for high-volume manufacturing, it will be necessary to switch to plastic injection molding. During the twenty years in which we have used rapid prototyping in our labs, we have been offered, completely free, other, often more sophisticated, machines. We have found that all these other machines have significant limitations from a design research laboratory perspective. SLA machines require expensive health-related photocurable liquids, laser adjustments and mirror refinishing. SLS machines require inert atmospheres, supplementary gases and expensive raw materials. All the latter are justified by large companies such as Rolls-Royce or GE, so the potential use of SLS-like processes for producing undercarriage parts or ultrasound scanners has given the not-inaccurate-but-exaggerated impression that all these machines can print a wide variety of parts cheaply.

Despite the often idealized portrayal of additive manufacturing as a mature and easily deployed process, the industry is still developing. The overly enthusiastic literature might lead readers to believe that additive manufacturing is a do-all, seemingly magical production solution, but this is simply not so. Additive manufacturing can provide creative, adaptable solutions in certain industries and, importantly, certain locales. However, this is not to say that intensive investment in additive manufacturing would allow a developing country to enter a global supply chain overnight. Currently and in the near future, additive manufacturing will be best suited to highly customized or low-volume, high value-added production. Additive manufacturing is simply another point—albeit, one with great potential—along the continuum of twenty-first-century manufacturing.

E. Fabrication by conventional processes and agile manufacturing

> "U.S. manufacturers who invested in technology, from robots to CAD software, have continued to thrive. They continue to make quality products profitably. In many cases, they have let go of factory workers. Yet in their place, they have hired other, more skilled technicians and engineers to keep their businesses running."
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> *Mechanical Engineering Magazine,* January 2012

Computer numerically controlled (CNC) machines, robotic loading-unloading-and-part-transfer, unattended material handling systems, and plant-level control systems are at the heart of the fully automated factory (colloquially referred to as the "lights-out" factory). Overlaid on this technology are the economics of substantial capital investments tailored to the expected batch (lot) size and product variation. The earliest plants to become fully automated in this way were more economical if they produced very large batch sizes of similar objects. To enable a modest amount of product mix, an analysis technique called group technology was very important in the early days of the automated factory. It allowed different consumer, or industrial, items to be geometrically categorized so that one particular CNC machine could produce slightly different parts with only minor tool and fixture changes, with only short delays in switching from one batch type to another. Flexible manufacturing systems (FMS) thus became increasingly established in the United States, the European Union, the Relublic of Korea and Japan during the mid-1970s. The underlying IT of faster computer chips (driven by Moore's Law), sensor-based CNC machines, software engineering, object-oriented databases, visualization tools, and computer-controlled coordinate measurement machines (CMM) for inspection enabled each generation of FMS to improve. With the increasing power of the underlying IT, "agile manufacturing" became the fashionable phrase of the 1980s/1990s as FMS became more reliable, able to handle parts with tighter precision, easier to reconfigure to smaller batch sizes, and, inevitably, less reliant on human oversight. From a developed country's viewpoint, this reduction in the need for human participation on the factory floor has become an irreversible trend powered by automation, IT and robotics. As a result, a visitor to the recently renovated River Rouge Complex—Henry Ford's original site—would see a variety of auto bodies in a variety of colours being welded together and painted with hardly any human oversight. Human assist teams are seen only in the final stretch, when some hand touches to the dashboards and interior fittings are needed. As early as the 1970s, the author and his colleagues could be heard to say, "The United States will lose factory jobs either to low-wage countries or to robotics and automation." In the 2010s, this trend will continue. Even when batch sizes are relatively small, because robots are now more sensor-based and programmed in more flexible languages, they can cope with reasonable product changes (along the lines of the group technology idea). When combined with a human who fully understands the quality control constraints, robots offer a powerful way to increase productivity. That said, high-wage countries will use even more automation to stay competitive with low-wage countries. Medium-wage countries will have to be more automated to stay competitive as well. The location of the low-wage country can vary—Asia, Africa or Eastern Europe. But in any country, a fabricator in agile manufacturing that wants to be competitive will depend more and more on automation. The trend is inevitable, with some minor variations thrown in on first-mover products, delivery speed and carbon regulations or taxes.

The choices for governments and firms in regions such as Latin America will be shaped continuously by the development of processes and strategies in the most advanced countries and by the most sophisticated firms. Developed countries (for our purposes here, members of the European Union, Japan, the Republic of Korea and the United States) already have no choice but to rely heavily on automation at the execution level. However, a huge need remains for skilled engineers to design the automation systems, to run the visualizations described earlier, to program and debug the operating FMS, to design and build machine tool fixtures and special tools, and to set up and maintain the machines and overall operations. Usually, there is also a great need for metrology technicians and quality control experts, who constantly need to measure output and adjust the machines to suit the specified quality of the product and desired specifications of design engineers.

As firms in the European Union, Japan, the Republic of Korea and the United States move out of the routine production ("sectors on the edge") of products and leave them to low(er)-wage countries, the need for tool makers and component/subsystem producers to offer design services to clients, as well as fabrication services, increases. One example of this is Timken, a company well known to design engineers as a world leader in bearing manufacture. As described in a recent issue of *Mechanical Engineering,*[154] Timken is an example of a firm in a developed country that has faced considerable international competition in routine ball-bearing manufacturing. However, by refocusing on higher-level design issues and even marketing itself as designing "friction solutions based on customer needs" rather than as a ball-bearing manufacturer, Timken has redefined itself by offering design services as a front end to the actual physical production of bearings and lubrication applications. This type of rebranding through focusing on services is made possible by the information and communications technology (ICT)-enabled services transformation discussed by Zysman et al. in chapter III. For routine bearings, the company invested in many forms of automation to reduce factory costs. But the greatest changes came from shifting into the bearings markets for off-road trucks, high-end performance vehicles and commercial trucks and high-volume industrial products, in which clients would pay for performance. These changes indicate the way forward for United States manufacturers but also the impact on jobs: the Bucyrus plant in Ohio, employs 400 people, which is far fewer than before, but many of them have technical or associate degrees. As noted in *Mechanical Engineering*, these newer types of manufacturing engineers "set up manufacturing lines to switch between products, monitor equipment, and make the judgment calls on when to take machines down for maintenance."[155]

A second example of how European Union, Japanese, the Republic of Korean and United States firms can prosper can be seen in the continued growth in the global market share of German automobile companies. Before any data is analysed, it is clear from daily observation that purchasing a Mercedes-Benz, a BMW or a Porsche is popular among educated consumers with a certain level of wealth; this is especially true in developing countries. The data show that exports to China from Germany increased much more than from any other country.[156] In high-value engineering, German companies have found a

[154] J. Mortensen, "Domestic or Offshore: Teardowns Help Reveal the Right Manufacturing Decision," *Mechanical Engineering* 2012: 24-29

[155] Ibid.

[156] "German Business: A Machine Running Smoothly," *The Economist*, February 3, 2011: 81-83.

combination of engineering quality and after-market service that has increased their share of global markets—and not just in automobiles. The *Mittelstand* (small to medium-size) companies are devoted to the manufacture of special machines for woodworking, printing and so forth. Manz Automation, one of the biggest producers of equipment for manufacturing thin-film solar cells, is an interesting example. Although Asian competition has reduced German production of the cells, the equipment upon which cells are made is still German.

Developing countries, whose advantage is based in part on deployable labour and low wage costs, will face the challenge of blending automation with hands-on labour in a safe working environment, enabling the production of high-quality goods that have a reputation for repeatability. To begin with, the earliest and most successful applications of robotics were in dangerous, heavy and mind-numbingly repetitive tasks that fatigued humans to the point of making mistakes. A low-wage country should therefore consider some robotic installations, if only to improve worker health. For example, paint spraying, investing casting and spot welding are tasks that should be automated for the sake of worker health and quality control. The next group is of assembly processes that are somewhat heavy and repetitive. After being debugged and programmed correctly, robotic systems outperform humans over a twelve-hour period and lead to a better-quality result. To maintain quality and Six Sigma[157] output, all countries, even low-wage ones, should install simple robots or automation systems to perform these highly repetitive tasks.

Two final comments are important here. First, education is essential for the new levels of European Union, Japanese, Korean and United States precision and highly automated manufacturing. Maintaining advantage for advanced countries in an era of advanced automation will hinge on the quality of their workforce. The success of German models is also tightly linked to specialized training in trade schools that supply the precision-conscious German auto and machinery workers. This is, in turn, bolstered at institutions of higher education, where the extensive Fraunhofer research groups are located next to the university campus or even on campus, so extensive, relevant research can be quickly transferred to industrial sponsors. Second, as discussed more fully below, agile manufacturing is a fundamental success factor in future manufacturing operations. Having achieved agile manufacturing, enterprises would be able to apply advanced computing operations to process large volumes of real-time manufacturing data and perform analyses and forecasting on productivity. In fact, the success of many firms proved that the majority of the revenue is made from the services that go with the tools.

F. Connectivity and supply chains

The underlying connectivity created by advanced IT networking is a key element in advanced manufacturing communities. Fast and reliable online communication between designers, fabricators and service agents is the first requirement

[157] Six Sigma is a business management strategy that uses a variety of quality management/control processes for the reduction of nearly all manufacturing defects (99.9996%).

for any country and any would-be metropolis in that country. An ability to speak English, Chinese or Spanish is also a major advantage because of the need to conduct conference calls or send email to clarify communications. Not surprisingly, Hong Kong and Singapore maintain their position in global commerce because they have both. India's education system and English-language heritage make it an obvious source for software supply and the Republic of Korea's investment in countrywide high-speed connectivity has prepared it for continued global commerce. A basic capacity for global communication, data exchange and commerce are needed by any developing country that wishes to be a part of global supply chains, made faster by reliable shipping and airfreight.

Beyond this foundation is the supply of services and products needed for supply chains, which are also at the core of lean manufacturing, described below. Supply chain strategy is needed to guarantee that all parts, modules and materials are available nearby and spontaneously resupplied to large-scale assembly houses. Anderson[158] writes that the grouping of products into families, the group technology described by Breznitz, is critical to efficient supply chains where parts are grouped by design, manufacturing and supply chain criteria. It is also critical to involve a firm's marketing department in evaluating the relative prospects of various product families. If the marketing department does not believe that sales prospects are positive for the product families that can already be made with the plant's existing machines and facilities, a decision must be made either to expand production and processes to accommodate the market needs or to restructure and remarket the existing product family groupings so as to take fullest advantage of sales potential. Ideally aggressive standardization is needed to drive as many similar and compatible subparts into a wide variety of platforms. Evidence indicates that the most efficient automakers do this within a family of cars. The use of the same subcomponents for several models—even though a cheaper alternative could be used—creates net savings for the company because the higher quantities will benefit from economies of scale.

Anderson writes that standard parts and materials can be made available in a spontaneous way through careful supply chain design. Obviously, steady flows of similar parts are best, and Dell is always held up as the best example of global efficiency in product similarity—to the point of obtaining sales revenue even before the remote subsuppliers are paid. Min/max storage ranges for raw material levels can be monitored by sensors and bar coding. Bar stock of extrusions, tubes and wire should be supplied in coil forms and cut to length at the point of use. In the highly efficient two-bin kanban system, one active bin of subparts drawn down while the second awaits behind to be moved into place at the last minute. These and other standardization tactics allow firms to capitalize on smooth supply chain design, thereby streamlining the production process so as to achieve efficiency.

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[158] D. Anderson, "Mass Customization's Missing Link," *Mechanical Engineering* (April 2011), accessed February 21, 2012, http://memagazine.asme.org/Articles/2011/April/Mass_Customizations_Missing.cfm.

Communication is key to success in IT-enabled manufacturing communities. External communication, made possible by stable, high-speed Internet, and familiarity with multiple languages (English, Chinese and Spanish in particular) is critical to capturing a particular node in the global supply network. Internal communication, however, is just as important for a firm's success. Building carefully crafted supply chains requires conscientious coordination between marketing, design and data management teams. Tight coordination and collaboration at this level is contingent on skillful internal communication systems, standardization techniques, and data management organization. Developing these skills will allow firms to maximize their supply chains, either by expanding current production or reconstructing existing product groupings to accommodate market expectations. Entrant firms looking to establish themselves in both middle- and low-wage countries will increase their ability to compete in global supply networks by honing the communication, coordination and collaborative power of their supply networks.

G. Lean manufacturing, sustainability and life cycles

Along the continuum of manufacturing, consideration should also be given to the ideal of sustainability. It is essential to recognize that sustainability is more than simply a strategy for environmental protection. Regardless of one's views on climate change, sustainability analysis provides a valuable tool set for producers around the world. As a contemporary buzzword, "sustainability" is often overlooked amid conversations concerning "value," "exports," or other concrete economic terms. However, sustainability should be recognized as part of the continuum of manufacturing because of its specifically competitive nature. The definition of "sustainable" states in part: "able to be maintained or kept going, as an action or process."[159] Thus, when we speak of sustainability, specifically sustainable manufacturing, we mean "stable or continuous production." Although there is clearly far more to the ideal of sustainable production, it is a start.

For a better understanding of sustainable manufacturing, it is worth reviewing the tremendous success of Toyota in the 1970s and 1980s. Japanese autos were flooding the global markets while American automakers struggled to produce vehicles competitively amid oil shocks and recessions. Toyota's success was widely linked to the development and implementation of Taiichi Ohno's Toyota Production System, also known as lean manufacturing. Ohno's lean manufacturing operated on the simple principle that one should reduce waste (*muga*)—processes that add no value to the product. If waste during production is reduced, goods can be produced at a lower cost.[160]

Lean manufacturing is recognized as a tremendous competitive success, and even today companies strive to become "leaner." This concerted, competitive

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[159] "Sustainable," in Dictionary.com, 2012, http://dictionary.reference.com/browse/sustainable?s=t/.

[160] This process is described in far more detail in Taiichi Ohno, *Toyota Production System: Beyond Large-Scale Production* (New York: Productivity Press, 1988).

effort to reduce waste is both "sustainable" and "green." Dornfeld[161] states in his blog: "the practice of lean manufacturing or lean production, if properly applied at a sufficiently detailed level with necessary additional information and data available is to me, inherently, green manufacturing." However, this "necessary additional information" determines the competitive success of sustainable practices.

"Sustainability" is a broad term, with even broader implications. Although the implementation of lean manufacturing provides a competitive advantage, it also subjects producers to increased vulnerability. For instance, lean manufacturing's success operates on the assumption of a stable supply chain. The question is not "if" but, rather, "how" firms should implement sustainable practices to competitively enhance their production systems. Even though "the environment" is a collective good, manufacturers are in the business of making profits, not protecting the environment. The varying degree to which producers can adopt sustainable practices is determined by the stability of their market and industry.

Many of the benefits of sustainability, such as environmental protection, stable supply chains, and the development of a "sustainable preference" among consumers, rely on the long-term success of a producer. Although the advantages of these long-term developments are apparent, albeit difficult to quantify, producers should focus first on the "low-hanging fruit" of sustainability. For instance, workfloor optimization and water reclamation/recycling processes can rapidly translate into the reduction of waste (and of lost profits). These processes are more likely to pay for themselves in the short term—a necessity for the many manufacturers surviving on an order-to-order basis or trying to penetrate existing supply chains.

Until environmental regulations are standardized throughout the world, or at least normalized through international trade tariffs that can penalize "dirty" producers, sustainability will be best pursued from a "lean" perspective. Reducing waste is a boon to both environmentalists and shareholders. Competition is a given in manufacturing. Therefore, sustainability should be pursued as a specifically competitive venture.

H. Service

> "Rolls-Royce's adaptability of its products, its expansion into services and global reach, could offer lessons for Britain's other industries. Rolls-Royce now gleans 51% of its revenue from servicing its engine fleet."
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> *The Economist,* July 30, 2011

[161] D. Dornfeld, "Sustainable Manufacturing; Is Green Lean?", November 12, 2009, http://green-manufacturing.blogspot.com/2009/11/is-lean-green-part-i-of-ii-part-series.html.

Based in Derby, United Kingdom since 1907, Rolls-Royce is internationally recognized not only as a manufacturer of luxury cars but a leader in marine vehicles and aerospace and commercial jet engines. Rolls-Royce is also a magnet for engineering research at the nearby universities, which include Nottingham, Loughborough and Oxford. The company now gleans much of its income from the sensors that monitor engine performance, the real-time analysis of the vibrations of the engine, (originally analysed by the Oxford researchers) and the ongoing monitoring services that can be offered in an after-sales manner.

The OnStar[162] automobile service plans developed by General Motors in the United States are in the same category of post-fabrication value-added. Other large companies such as GE and Siemens see this category of after-sales service contracts as their biggest growth area.

Changing customer requirements are the key driver of the manufacture-plus-service package that is emerging in high-end engineering products: vehicles, aerospace, servers and machinery. The purchase price of specialized machines may be less important than its reliability and the support and services that are sold with it, as noted in the section on German machinery suppliers. In view of the manufacturing, sales and ongoing support involved in a Rolls-Royce jet engine, the owner of an airline is highly motivated to schedule preventive maintenance in a large hub such as Heathrow, San Francisco or Bangkok where it has the necessary facilities. The unpleasant alternative may be to cope with an unexpected landing on a Pacific island with stranded, furious passengers; repair parts flown out to a remote location; and the loss of flight miles. Over the course of a decade or more, the service offered by Rolls-Royce has become increasingly sophisticated. The traditional level of twentieth century after-sales-service was in spare parts, repair and overhaul. These have been enhanced through the ability to supply performance data and forecasting services, technical and logistics support and customer training.

I. Conclusion

We conclude with some economic realities that underpin this technical review. The issues of cost, quality, delivery (time-to-market) and flexibility of the production system will always guide the development of products in the market. Inevitably, any firm must add the rising costs of adding higher quality, faster delivery, or having a more flexible manufacturing and supply lines. These factors influence all stages of manufacturing.

First, considering the ideation and design phases of a new product, it would be tempting to imagine that the "lone designer" referred to in section A could spring up in any country and launch a new product on the global market merely by having access to the rapid prototyping bureaus in section C. While this is not impossible, it is first important to think about connections to markets, investments and the cost of downstream manufacturing in volume. In an area such as Silicon Valley, many

[162] OnStar, "OnStar: Live on Services," 2012, www.onstar.com/web/portal/home/.

of these “lone designers” make a respectable living by developing a “looks like” and “works like” prototype and shopping it around to investors and would-be manufacturers. As we describe in section A, ideation usually requires a substantial network of experienced people who want to see the device in person, bounce the idea to marketing consultants, and even work as a hands-on team to scale the product. Scalability is the key issue. For the foreseeable future, it is highly unlikely that the rapid prototyping services (additive manufacturing, 3D printing, etc.) can offer volume production. We challenge readers to merely look around their house or office at the everyday products made in the millions and sold at the large “big-box” electronics or other consumer stores. Today, nearly all these items are made in plastic using injection molding—and this is the challenge. Even when a part has been made using rapid prototyping, it must be slightly redesigned for injection molding to show the draft angles to remove the part from the mold; to allow for the shrinkage of the plastic as it cools; and to avoid “hot-shorts” that occur because plastic will not run down a long channel to the very end. Meanwhile, the internal printed circuit board of the toy or consumer device must be redesigned to suit wave-flow soldering techniques and board layouts. Our research indicates that the benefits of cloud computing and social networks allow us to begin a project connecting newcomer designers in high schools or art communities to experienced mold designers who are “out there on the Internet.” This type of project might indeed connect design repositories of new parts with experienced manufacturers. However, this effort is a work in progress and might take a decade to take root as a way of jump-starting a full industry, as opposed to a service for hobbyists and artists.

Second, a truly new product or service must break into an existing market and show how it provides substantial advantage over the incumbents and generates long-term value. As one example, the authors tried to launch the CyberCut web-based design and manufacturing system during the 1990s. Over a decade later, this system has been largely realized by eMachineShop.com, which allows customers to download and use a CAD system to create a custom part, obtain a quote, and order a part that will be delivered in reasonable time depending on complexity and relevant process. The bugs in this system have been worked out over time, as usually happens with new ideas in manufacturing. Combined with this mechanical design, the inner electronics can also be turned into printed circuit assemblies at fabrication houses such as pcbfabexpress.com. In the event that the original designer wants to scale to a larger run, the ability to do so is a matter of capital investment. Depending on the complexity of the product, months might be required to scale up and adjust a production process so that it will operate efficiently (whether in-house and outsourced).

Despite the unique challenges of manufacturing/fabrication, large economies of scale are possible when core manufacturing is offered as a base platform to designers and developers for ideation. Manufacturing still matters: Having a first-rate manufacturing capability is, in our opinion, mandatory for a country’s economic growth.[163]

[163] S. Cohen and J. Zysman, *Manufacturing Matters: The Myth of the Post Industrial Economy* (New York: Basic Books, 1988).

Awareness that factories are located in a nearby physical environment offers a large psychological incentive as "the end point of invention or innovation." Zysman and Cohen[164] write that to be an expert in the next generation of a product (especially in semiconductors), a firm must be an expert in the present generation. Otherwise, the tiny design-for-manufacturing (DFM) nuances will be lost. If the United States and the European Union continue to outsource the base platforms for manufacturing (to capture short-term gain), it is highly likely that the locus of engineering design will eventually relocate to other countries. Certainly this is already taking place in India for software and in China for certain kinds of research. Not that this is a bad thing overall. It means that all countries can benefit from higher-value front-end design, but it will have unwelcome consequences for job creation in the United States and the European Union.

A metropolis focused on fabrication and agile manufacturing is connected to the rest of a country's economy. Again, quoting Kaushal, Mayer and Riedel,[165] the basic United States manufacturing sector is interconnected with equipment maintenance, transportation, scientific and technical services, and construction for manufacturing enterprises. Adding these factors raises the importance of manufacturing to around 15 per cent of the United States workforce rather than the current 9 per cent. Furthermore, as noted in many recent popular articles, a manufacturing plant is a "magnet" for many other related services. When a new auto assembly plant opens, it attracts more shops and services of all kinds and creates jobs at the local power, gas and water utilities. Sadly, the reverse is true after a steel plant closes down: the town loses jobs in all sectors.

In conclusion, the production-line assembly of new products, such as the iPad and iPod, is merely a thin slice of the very rich continuum of twenty-first-century manufacturing. The rise of information technology has ushered in the ascension of complex global value chains (GVCs) and cross-national production networks (CPNs). Increasing fragmentation in the phases of production opens up new points of competition among manufacturers along the value chain and raises new questions of where and how to capture value. To understand the evolving organization and dynamics of global manufacturing, we must shift our focus from sectors of production to stages of production. ICT-enabled tools have allowed the geographical distribution and decomposition not only of production but also of the very means of designing and producing goods.

IT has transformed where and how goods are produced at each point along the manufacturing continuum, including ideation, design, prototyping, fabrication, supply chains, sustainability and engineering services. The underlying connectivity created by IT networking brings forth new opportunities and challenges for advanced manufacturing. From the lone designer able to realize a vision in prototype form to the complex manufacturing facilitated by virtual assembly to the rise of engineering services, ICT-enabled tools are the key facilitator. As this chapter shows, technological developments including additive

[164] Ibid.

[165] Kaushal, Mayor and Riedl (2011).

manufacturing (popularly labeled 3D printing) and robotic factories have changed the face of manufacturing. Fast and reliable communication networks between designers, fabricators and service agents are a key element to this evolving manufacturing continuum and offer opportunities for developing countries to build links with developed countries. Developing countries that want to capitalize on these opportunities must prioritize building ICT networks and communication platforms.

Paradoxically, as ICT tools drive the shift toward greater automation, they will also require the development of a more skilled workforce to remain competitive. In developed countries, manufacturing is responsible for many millions of jobs focused on front-end, innovative design and analysing and servicing these sophisticated, high-value products. Just as developed countries must continue to invest in the education of their workforce to maintain their existing design and manufacturing competency, it is essential that developing countries with an interest in fostering such manufacturing competencies observe these lessons and focus their development appropriately. Developing and low-wage countries will eventually be obligated to introduce automation for worker health, efficiency and productivity. Although automation alone is far from a guarantee of success in today's global value chains, it is an essential part of developing the manufacturing capacity upon which industries can compete and progress in today's international economy. Adopting this synergistic combination of education and advanced manufacturing is particularly important for developing countries that seek to compete with China's overwhelming dominance in creating economies of scale. The development of a flexible, creative, and educated workforce will thus play an important role in retaining a competitive edge and capturing value in GVCs. Then, product differentiation, customization and design, which have been changed in terms of accessibility and process by evolving technological breakthroughs, will play a crucial role.

The major challenges in creating a vibrant manufacturing sector in both developed and developing countries are the growing complexity of processes and supply networks, cost pressures and growing customer expectations for quality, speed, and custom products. Achievement in these areas, if facilitated by IT tools that facilitate the main transformation from unskilled labour to advanced automation, an encouraging business environment conducive to creating global value chain and service networks, and government policies that invest in higher education to ensure the development of human resources, will no doubt lead to more possibilities, more nuanced competition and faster economic growth. Moving forward, it will be imperative for countries to realize such emerging trends in advanced manufacturing, so that they can determine where and how their national firms can participate in that innovative process and thereby capture the greatest value from the globally integrated production process.

In short, we end our study where we began. Twenty-first-century manufacturing is at once a strategic asset and a valuable commodity. For firms and places, playing the game successfully requires the ability to identify in which stage of production they can compete. In the current dynamic market system, firms and places must continually re-evaluate and redirect their efforts if they are to capture the "sweet spot"[166] in the market.

[166] J. Zysman, "Production in a Digital Era: Commodity or Strategic Weapon?" BRIE Working Paper 147, 2002.

Concluding remarks: 21st century manufacturing

John Zysman[167]

Five issues were developed in this analysis.

Who produces what and where?

Manufacturing companies, it is well understood, have broken apart the production of their input components, from research down to final assembly, and source them both internally and externally throughout the world. While the aggregate trade data succeeds in reflecting the basic changes in the structure of global production, such as the emergence of China and Asia as a hub of global production, it fails to illuminate the decomposition of production. The aggregate data does not tell us how supply networks actually operate to produce final goods that go to the final user, whether consumer or industrial, or where the value lies in the supply network.

Where is the value in the value networks?

Detailed case studies show that while many of the jobs are moving away from the richest countries, much of the value in the products remains in the wealthy nations.

Services, ICT-enabled services, now come with everything.

One reason that value stays in the advanced countries rests, increasingly, with the role of information and communication technology (ICT) enabled services embedded in products. Phrased differently, the value of an object is increasingly the digitally enabled services it can provide.

Increasingly, analytic focus must be on phases of production, rather than sectors of production. Where and how goods are produced has been transformed by an array of technological developments.

The face of manufacturing will change with the emergence of additive manufacturing, popularly labeled 3D printing and robotic factories. The ICT revolution is at the core of all these changes.

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