Escape from the Commodity Trap

Will the Production Transformation Sustain Productivity, Growth and Jobs?

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Abstract

The emerging transformation of the production of goods and services is dramatically altering what is produced, where, how, and who captures the value. It creates opportunities and challenges. Part I of this essay examines the transformation of production and its acceleration by Cloud Computing. A first argument is that the transformation of production, including both manufacturing and ICT-enabled services should be our focus. A second argument is that ICT enabled services are a source of distinct value in the economy. Third, it considers the distinct and contradictory challenges facing manufacturing. The fourth argument is that the transformation of production will be accelerated by the emergence of Cloud Computing as the next Information Technology Platform. Part II of the essay makes a few focused policy suggestions and considers several issues policy makers need to consider as they frame policy. The emphasis is on the role of next generation tools and competencies of "places". The crucial policy question is how to nudge that transformation in the advanced countries toward higher value added, higher skilled, higher wage solutions.

Executive Summary

For the advanced industrial democracies to expand the real income of the citizens and sustain growth in employment and productivity, their economies will have to escape from the Commodity Trap. The commodity trap is the price-based competition throughout markets for standard goods and services, which puts pressure on wages and profit margins alike. Clearly, the way out of this trap is to create distinctive high value added products – both goods and services. The emerging transformation of the production of goods and services is dramatically altering what is produced, where, how, and who captures the value. It creates opportunities and challenges

This study examines the processes and consequences of the transformation of production. Part I of this essay examines the transformation of production and its acceleration by Cloud Computing. The arguments developed in that section are highlighted here.

- First, the transformation of production, including both manufacturing and ICT-enabled services should be our focus. The decomposition of production, moreover, further blurs the meaning of the distinction between services and manufacturing.

- Second, ICT-enabled services are as much a source of productivity, employment and growth as manufacturing. These services systems must be developed and built.

- Third, manufacturing is being pulled in two directions. On the one hand, the decomposition of manufacturing, and indeed of ICT-enabled services, has produced complex cross-national supply networks. In some countries, including the United States, that decomposition has decimated the core infrastructure of skills and knowhow required for competitive advantage in production. On the other hand, the rapid evolution of advanced manufacturing has encouraged the re-composition of production, the reintegration of development and production. Both processes will endure. A core question will be when a firm or place must control production to

maintain a competitive position as products and technology evolve. A mosaic will result from strategy choices by firms and policy choices by "places". The question is when will manufacturing be a strategic asset and when a vulnerable commodity.

- Fourth, the transformation of production will be accelerated by the emergence of Cloud Computing as the next Information Technology platform

Part II of the essay makes a few focused policy suggestions and considers several issues policy makers need to consider as they frame policy.

- The analysis focuses policy on the tools required to implement the transformation, on the competencies "places" require to succeed in the transformation, and the possibilities of direct government action.
- In framing the policy debate, the analysis suggests that policy makers need to consider when production is a strategic asset and when a vulnerable commodity while continuously evaluating whether the production transformation will be seen as merely a revolution or a real revolution.

The crucial policy question is how to nudge that transformation in the advanced countries toward higher value added, higher skilled, higher wage solutions.

Introduction

The commodity trap

For the advanced industrial democracies to expand the real income of the citizens, to sustain growth in employment and productivity, their economies will have to escape from the *commodity trap*.[2] The decomposition of manufacturing and services, outsourcing, and the redeployment of production activities around the globe, off-shoring, has created for the advanced countries a commodity trap. Communications technology and container shipping together facilitated the decomposition and the geographic redeployment of production. One consequence was that skills and knowhow were transferred to competitors often dissolving clusters of capacity in the advanced countries as related clusters are built elsewhere. That in turn generated numerous points of competition throughout supply networks. 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. Drawing on the widespread availability of conventional technology, an array of firms from diverse countries entered the markets. Price-based competition throughout markets for standard goods and services resulted and put pressure on wages and profit margins alike. If everyone can produce a good or service, the resulting intense competition leads to commoditization. Commoditization is competition based principally on price. There are always places where cost can be driven down by, for example, lower cost labor or subsidy of investment. The “commodity trap” with intensified price based competition on most conventional goods was set. In sum, this decomposition of manufacturing and services, outsourcing, and the redeployment of production activities around the globe, off-shoring, has created for the advanced countries a commodity trap.

Debates emerged in the advanced countries asking whether manufacturing jobs were moving “off-shore” in response to cheap labor, whether automation would erode employment from the production that remained, and what policies were required to sustain growth in employment and productivity. It is easy to say that the way out of the trap is to create distinctive high value added products, both goods and services, or to create distinctive defensible positions in the production and distribution of lower margin more commodity-like products. The real challenge is how to do that.

The ongoing transformation of the production of both goods and ICT enabled services creates an opportunity to escape the commoditization trap by dramatically altering what is produced, where, how, and who captures the value. Production is being transformed, not just manufacturing, and the very place of ICT enabled services in value creation and the economy is being altered.[3] The crucial policy question is how to nudge that transformation in the advanced countries toward higher value added, higher skilled, higher wage solutions.

As we begin we should be clear that the transformation of production means that routine work will be automated and that capital will replace labor. Job skills and work organization will be recast. Moreover, that process of transformation is being accelerated by the emergence of *cloud computing*, a new Information Technology platform that facilitates widespread lower cost access to computing resources. Some see this production transformation creating a jobless world, or at least a world in which a semi-skilled, semi-employed populace contrasts with a skilled,

wealthy elite. Will the Luddites be correct this time? Or, as so often before, will employment and income ride a wave of technological innovation that creates, as so often before, a surge in productivity and jobs?

Our ultimate concern in this essay is how firms compete, where they locate production, what skills are required, and what wages and benefits are supported. We need to ask two questions: First, Who will produce what and where? Second, Where will the value be located within the value networks? The answers will determine what this transformation means for jobs and competition.

The outcomes, in any case, will be shaped by policy; not dictated by the evolution or application of the technology. The drive toward Rapid Innovation Based (RIB) growth in the past years has clearly shown how variations in national policy can shape the character of the positioning and success of firms in the global market, with clear-cut differences in the distribution of wealth and income.[4] There are no magic strategic bullets for sustaining growth of jobs and productivity; there are only an array of options and choices. The crucial policy question is how to nudge that transformation in the advanced countries toward higher value added, higher skilled, higher wage solutions.

Part I of this essay examines the transformation of production and its acceleration by Cloud Computing. *Part II* of the essay makes a few focused policy suggestions and considers several issues policy makers need to consider as they frame policy.

Part I

The Escape?
A Transformation of Production

Production remains of vital importance in the digital age – not only in the traditional manufacturing industries but also in the services sector. The story of transformation has three parts:

- **Services** are transformed by Information Technology, changing how firms compete and value is created. The development and deployment of these ICT-enabled services should be considered a form of production.
- 21st Century **manufacturing**, is likewise being transformed by Information Technology, whatever list of innovations one points to. Manufacturing is being pulled in two distinct directions: decomposition of production, on one hand, and reintegration of production, on the other. There will be a mosaic of outcomes, not a single result.
- These transformations of production, both the ICT-enabled transformation of services and a revolution in manufacturing, are being accelerated by the emergence of **Cloud Computing**, the next Information Technology platform.

'Services with everything': service takes the form of production[5]

ICT-enabled services, those services facilitated by the application of rule-based Information Technology tools, have become a source of dynamism in the economy. This dynamism is the focus in this essay. Services are no longer an economic sinkhole, immune to advances in technology or organizationally-driven increases in productivity.

Importantly for our discussion, ICT-enabled services rest on capital-intensive infrastructures and share important characteristics with manufacturing. It is now outmoded to say that services are consumed as they are produced. Google server farms, for example, establish the latent capacity, an inventory if you will, to respond almost instantly to demand. And that collection of server farms requires capital investments of billions of dollars.

Let us focus on how ICT generates dynamism in services. The ICT-enabled service transformation is economy-wide, creating services with everything. It is not limited to traditional information rich sectors such as finance, insurance, and entertainment.

The algorithmic revolution - Let us begin at the beginning. The application of rule-based ICT tools to service activities transforms the services component of the economy, altering how activities are conducted and how value is created. We call this the Algorithmic Revolution.[6] The development and operation of digital service applications, whether games or music services, become sources of innovation and employment. Embedding services in existing products makes the manufacture of the goods themselves a necessary, though not sufficient, basis for competitive position. This shifts the location of value creation and high wage employment. But we turn to this later.

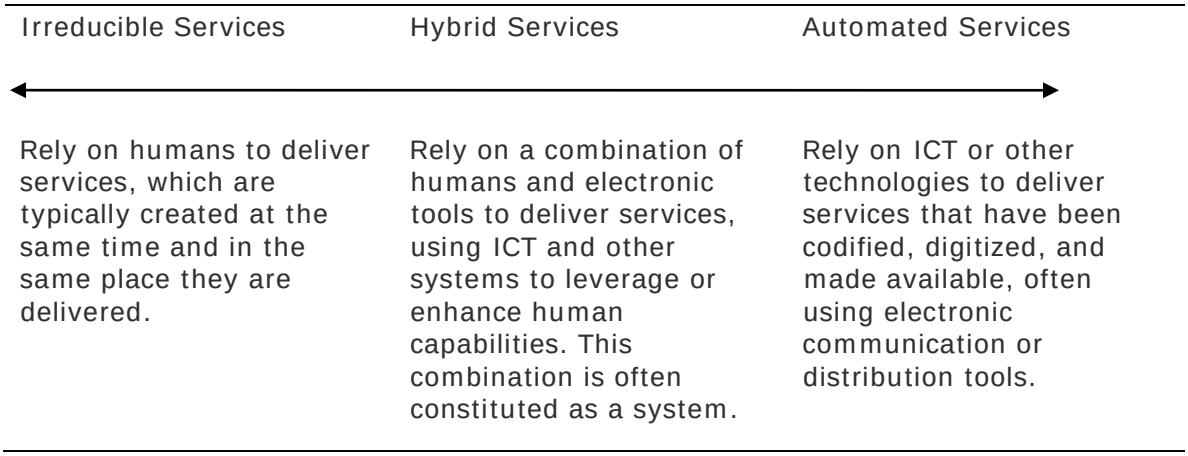
In the Algorithmic Revolution, tasks underlying services can be transformed into formal, codifiable processes with clearly defined rules for their execution. When activities are formalized and codified, they become computable.[7] Processes with clearly defined rules for their execution can be unbundled, recombined, and automated. The inexorable rise in computational power and the development of sensor technology means that computable algorithms can express an ever-greater range of activities, and a growing array of service activities are reorganized and automated.[8] The essential point is that the codification of service activities allows the rapid replication, analysis, reconfiguration, customization, and creation of new services. It allows for business models to become more productive through extension with ICT tools and for entirely new business models to be created, offering services previously impossible at any price. The Algorithmic Revolution in services profoundly changes how firms add value.

Firms find that existing activities often take on new purposes and create new forms of value when converted into computable processes. Big Data, the latest flash in the ICT discussion, is precisely a by-product of this transformation. The act of making a purchase at a supermarket or retailer, for example, has been transformed from a simple monetary transaction into a data-generating activity. At the beginning of the application of ICT to retail, inventory was simply monitored.[9] As systems evolved, customer purchasing patterns could be examined with increasingly detailed understanding of who was buying what, and why. Retailers could capture consumer preferences and consumption patterns 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. It then leveraged its ability to analyze this data by offering pharmaceutical firms a service to monitor the reactions of test subjects to drugs.[10]

The impact of the ICT-enabled service transformation is pervasive. It is not just a matter of finance, insurance, retail and entertainment – sectors that are at their core about information and hence directly affected by the revolution in information. Rather, services are increasingly embedded within products, supporting the sale of products as in automobile communications and entertainment. Indeed, often the manufactured products are sold as delivery mechanisms for the services: MP3 players are portals to music stores, cranes are entangled with port-management services, and agricultural equipment is now a mechanism for managing soil content and allocating fertilizer.

The services spectrum[11] – Services activities can be placed on a spectrum ranging from those irreducibly delivered by humans, on one end, to the automated services that are replacements for people, on the other. (see Figure 1). The character of the underlying service activities, not the packaging or branding, distinguishes these categories. The spectrum proposed here applies to government activities as well as firms.

Figure 1. The Services Spectrum



The most dramatic are highly automated, information rich offerings such as Google search, Skype, or Netflix. These *automated services* rely on ICT to manage information and deploy it in ways that are useful and valuable to customers. The services provided by an automated teller machine (ATM), an Internet travel agency, or electronic systems for collecting road and bridge tolls are familiar examples.[12] Many automated services reinvent existing services, either threatening manual services or extending their reach. In some cases the extended reach amounts to fundamentally new services. In one sense, eBay's online auctions might be thought to 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. Similarly, 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. Thus automated services extend from purely information services through networked devices and objects in what is increasingly labeled an Internet of Things.

Fully automated systems such as these, 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.

Services at the other end of the spectrum continue to rely fundamentally on humans for delivery; they cannot be reduced to algorithms and computations. Even *irreducibly human services,,* from restaurants to building maintenance show signs of transformation. [13] These services 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. The effect of ICT on irreducible service offerings is visible in online reservation systems for restaurants, such as Opentable in the United States, or the ICT -intensive management systems that create a global building maintenance business for ISS in Denmark and Johnson Controls in the US. Other 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. These services are often supported, augmented, by ICT technology. Examples include routing/booking systems for taxis and limos, reservation systems for restaurants, and complex management systems that improve the productivity and working conditions for building maintenance.

Finally, a growing proportion of the most valuable and popular services are now hybrids. *Hybrid services* combine human and machine-based capabilities: either harnessing technology to improve and to leverage the human abilities or depending on human talents to augment, deliver, customize, personalize, and otherwise add value to networked automated services. These hybrid offerings integrate people and machines. The embedding of ICT-enabled services into cranes or agricultural equipment, for example. changes the way we farm and run ports. Accountants often rely heavily on software solutions for information about tax rules, bookkeeping systems, and financial principles. With this software, human service providers are able to store, analyze, update, and manipulate large amounts of data with ease, speed, and accuracy, but they supplement the power of the software 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.

The hybrid sector of ICT-enabled services: a closer look – This spectrum, though, may understate or miss the way competition in goods is becoming competition in the services they provide. I propose that the deepest and broadest economic transformations are those which interweave ICT-networked, sensor-enabled products – such as nursing aids, cranes, or cars – with human delivery and judgment. The value of hybrid services depends on having human capabilities augmented by increasingly sophisticated ICT systems. These hybrid services are distinctive for several reasons: [14]

ICT-enabled service offerings enhance physical products. Products can become portals to services or embedded elements of a service. To begin, we note that Apple's iPod is more than an attractively designed MP3 player. The iPod's integration with the iTunes software was critical to its commercial success. Ultimately, the iTunes online music store revolutionized the way in which music is sold. The iPhone's capability to act as a conventional phone is not its primary competitive attribute. 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.[15] Similarly, Amazon's electronic reader, the Kindle, is a product, but its primary value is derived from its integration with Amazon's online bookstore and magazine offerings.

The story goes well beyond media sectors, plunging into the core of the industrial economy. Jonathan Murray tells the story of Wireless Fasteners. The helical screw is so familiar today, but cutting a thread around the screw was a revolutionary innovation when introduced widely in the 1400s. These screws 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 labor-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 defense.

Kenji Kushida has emphasized that 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, analyzed, and sent wirelessly to a remote database, which both helps "map" the fertilizer applied and adjust the fertilizer mixtures in real time.

Core businesses shift from selling goods/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 into a services company that embodies products in its offerings. Emblematic of this transformation were IBM's sale of its Thinkpad notebook computer division to the Chinese company Lenovo, spinning off commodity hardware, and its acquisition of PricewaterhouseCoopers' consulting arm, building up the capacity to deliver services. While IBM still derives significant profit from its hardware offerings in markets where it has advantages, 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.

As a precursor of the future of the ICT-enabled services transformation, Jonathan Murray urges us to consider the Chilean mining company CODELCO, the world's largest copper producer. In this case it is a story of moving from mining to mining as a service. Note this is not about services to mining, but mining as a service. To increase worker safety and improve productivity, CODELCO embarked on a program 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.

The Internet of Things: 16 The observation that networks of interconnected objects could create distinctive services and products, whether entirely automated or with human intermediation, has created a new category. Companies have given it their own spin for competitive advantage; Cisco coined the Internet of Everything. GE talks of

the Industrial Internet. In each case networks of objects provide means of escaping a firm's particular commodity trap. Their strategies are thus extensions of the categories we have discussed so far.

The unsettled boundary between products and services: 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. We call Quicken a software product if it is purchased as a CD in a box, but call it a service if the same software engine runs online, 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.

One consequence of this ICT enabled service transformation of product, is that conventional distinctions made among economic "sectors", such as cameras, are collapsing into "value domains", such as mobile apps. The digitization of information brings previously physically distinct products and sectors into competition with one another in less clearly defined customer bases.[17] The block of plastic that we call a phone morphed into a Smartphone – providing a variety of different digitally based functions and services. One often hears the story of music, but equally interesting is the story of photography. 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. Thus, ICT-enabled services extend competition within distinct sectors into competition over "value domains." More players are involved, and there is less clarity over the boundaries of previously distinct product and user categories.

An additional consequence is that even counting manufacturing jobs or measuring manufacturing output is made much more difficult as service and products become ever more tightly integrated. The category of services is for many purposes already nearly meaningless: the classic definitions of service no longer apply when services are heavily involve or are delivered by built systems with latent capacity. The category of services is, in any case, a conglomeration of diverse activities, comprising everything that is not manufacturing, mining or agriculture.

ICT, the decomposition of production, and the ambiguous character of services – ICT, we all understand, contributes to the decomposition of production in services and manufacturing: the outsourcing of services that are linked to manufacturing,. Certainly that decomposition facilitates outsourcing and offshoring of production with consequences for employment. The outsourcing itself, buying services outside the firm structure, has significant impacts. One consequence important for policy analysis is that our statistical and analytic understanding of the economy is distorted. Twenty-five years ago, Steve Cohen and I emphasized that a window washer working for General Motors, Lego, or Acelor is considered a manufacturing employee.[18] When Hewlett Packard hires the Danish firm ISS to manage their buildings, that same window washer is now counted as a service employee. Manufacturing employment drops, while services employment rises, but at least initially the same activities are being performed in the same place. The decomposition

of production changes the numbers counted in services and manufacturing. Consequently part of the perceived decline in manufacturing employment, but only one part, is an artifact of how we count. Of course, some service activities that were once tightly linked to production, such as accounting, will now be off-shored as well as outsourced.

The outsourcing has another important consequence: sparking innovation. General Motors is not likely to be an innovator in window washing. Importantly, however, ISS and Johnson Controls are innovating building maintenance services. So the decomposition, the outsourcing, is facilitating innovation with the reorganization and ICT based scaling of these services (a longer statement of the argument is in the footnote).[19] As analysts or policy makers, we must examine the interplay among outsourcing, employment in production generally, and innovation.

As a result of the ICT-enabled transformation of services, the continuing debate in political, economic, and public policy circles about the relative value of service-sector jobs and manufacturing jobs is increasingly irrelevant to policy debates in the real economy. Just as it was inaccurate to assume that manufacturing jobs are secure and well paid, it is also inaccurate to consider that the bulk of service jobs must be dead-end, low-wage, unskilled positions. Often, too sharp a distinction is drawn between the dead-end fast-food worker and the investment banker. The key questions will be how the new technologies are used throughout the economy, what types of jobs are created, and how everything from retail to window washing is transformed.

We should not focus on the increasingly irrelevant distinction between manufacturing and services, but rather we should recast the conversation. The word “production” should include not only traditional manufacturing but also the development of ICT-based services—with the know-how, skills, and tool mastery that they require. Let us underline this point. Development and deployment of ICT-enabled services should be considered a form of production. In fact, the ICT-enabled service systems must be built, and the service products that are part of the networks must be imagined, designed, and built. Consequently, ICT-enabled service systems are very open to innovation and productivity increases.

Taken 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. Production workers—including not only assembly-line employees but also many kinds of knowledge workers in service industries ranging from finance, health care, and ICT to education, media, and entertainment—are now more important than ever.

From a corporate strategic standpoint, the question is how to conceive, design, develop, build, and deploy a new system. From a policy standpoint, we note that there will be so-called “good” jobs, ones with high-value added functions, in the innovative development, implementation and deployment, and operation of these systems. Policy makers should employ strategies that will help communities and firms to develop the competencies required for this new form of production.

The ongoing manufacturing revolution: decomposition or reintegration? [20]

What is being produced, where and how it is being done, are all transformed. Our concern, to remind ourselves, is with location, employment skills, and distributional

consequences of production. Information technology's influence on manufacturing would certainly include computer-aided design (CAD), virtual prototyping, novel materials, and new production processes including 3D printing. Many would expand such a list to include large-scale data analytics or sophisticated scheduling and supply chain management.

The individual elements are themselves of significance. More importantly, taken together they reopen the questions of how manufacturers will organize production, how they will address their markets, and indeed where they will capture value. Some ask whether a new manufacturing system will emerge.[21] I would ask whether an entirely new production system, of which changes in manufacturing are a part, is emerging with the ICT transformation of services, the expansion of hybrid services, and the embedding of services in physical products. Will we see a version of the existing system with more capital and fewer workers, or something radically different? Indeed, we are likely to see a mosaic of co-existing production systems reflecting diverse corporate and policy choices about how to deploy and implement the new technology possibilities.

The question of what a new mosaic of production solutions will look like should be set in historical perspective. What we make, how, and where has evolved over centuries with developments in power, materials, and the technical as well as social processes of control. Indeed, one can trace epochs of production engineering by steps in process control, both technical and social.[22] Each epoch was marked not just by technology innovation, but also by innovations in the social organization of work and the skills required for success. It is useful to trace the historical evolution of dominant production paradigms. However, if we must never conclude that a dominant paradigm is the essential or singular feature of a particular era. Dominant paradigms at any moment obscure the profound enduring diversity in production solutions.

Nonetheless, there are dominant approaches at any given moment, or at least production models that are taken as icons of the "modern" or the "future". The "Fordist" paradigm of vertically integrated manufacturing dominated the first part of the 20th century until the Japanese model of lean production displaced it. [23] Japan's just-in-time "lean" production system evolved from pre-war structure and from post war shortages, driving the nation's surge in manufacturing competitiveness. "Lean" production was an innovation in management: a social and conceptual revolution in production. It brought immediate benefits, such as directly lowering costs by reducing inventories and created the feedback on which continuous improvement was possible. In the Japanese case, distinctive technology followed social and business organization, rather than leading the way.[24] Indeed the entire trajectory of Japanese machine tool development reflected new ways of organizing factory flows.

Global supply networks and the decomposition of production characterize late 20th Century production. These supply networks, developed in part as a competitive response to the advantages of lean production, diffuse particular production steps and specific skills across regions and countries.

Will a single dominant paradigm, an image of production, emerge in this era? The dynamics that will shape the evolution of 21st Century manufacturing can best be understood by considering a tension between *decomposition* of manufacturing with specialized, often geographically specific, "phases" of production and the possibilities for advantage from the *reintegration* of these phases into a unified innovative whole. Both processes are driven by or facilitated by developments in information and communication technologies. Will the increasing availability of computing capacities generate a highly decentralized system of production and distribution?[25] Will choke points emerge at which large producers can exert control over the system? [26] Will a

reintegration of production see production leadership returning to the advanced countries?

The redeployment of production[27] **–** The deployment of communications technology and container shipping together facilitated the geographic redeployment of production. [28] That process has had two significant consequences. One consequence in the advanced countries is that skills and knowhow are transferred to competitors, which of course drives and accelerates the commodity trap. That transfer can also dissolve clusters of capacity in the advanced countries as related clusters are built elsewhere. In the United States, off-shoring of production capacities has, some argue, undermined the supply base of skills and firms, making a return of manufacturing more difficult.

A second consequence is that with that redeployment, manufacturing turned away from a sectoral focus in which clusters of production were built around a few firms in a particular segment of industry, often rooted principally in just a few locations, such as Detroit for American automobiles and Nagoya, or indeed Toyota City, for Toyota. Manufacturing evolved to distributed cross-national production networks.

Critically, the manufacturing activities were not randomly redeployed. Dan Breznitz characterizes the evolution:

> "…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). [29]

Yet, as Breznitz argues, "…geography still matters….and… (geographic) specialization is still occurring"[30].

> "…rather than focusing on entire sectors, we need to refine our thinking and start to analyze specific phases of production in particular industries as the main loci of clustering. There is, consequently, an increased need to analyze manufacturing issues from the perspective of phases of production rather than by sector. However….the existing aggregate data is not organized in a way that is appropriate for this analysis.[31]

The phases blur in practice, but are important to distinguish.

- Novelty product development. In the most radical form the new product consists of not just a next year model automobile, but a fundamentally new product such as the ipod or iPhone. Silicon Valley specializes in product design, sometimes generating entire new product segments. There are other versions of novelty development, but Silicon Valley is the best known.
- Design, prototype development, and production engineering are next.
- Actual production follows, often undertaken by a contract manufacturer such as Foxconn.
- Separately, not in sequence, we need to identify second-generation product development. As Breznitz argues: "Firms working at this stage specialize in how to make existing products and technologies better, more reliable, and more appealing to wider groups of users."[32] This is more an other than just "fast following" or "incremental" innovation.

Innovation, job creation, and productivity growth are possible in each phase. The Silicon Valley is not the sole model of the future. The Silicon Valley model generates huge returns for some shareholders, but not necessarily surges in production employment for the region itself.

With this redeployment of production, where does the value locate? Even as jobs move offshore, the firms of advanced countries tend to retain the value. Martin Kenney reviewed an array of sectors including toys, apparel, electronics, shoes, machine tools, and automobiles, concluding that while employment moves to lower wage locations, value remains in the advanced countries. [33] In turn, the bulk of the value that stays in advanced countries is captured by IP, brand, or a dominant distributor. The advanced country workforce is often left out. Jobs thus move offshore while value moves to the holders of the IP.

The reintegration of production– The counterpoint to the decomposition of production is the reintegration of production. There are hints, a few instances, of production coming back to the advanced countries to more effectively reintegrate the production phases noted above. The driver is innovation in production, including innovation in tools and materials, which in turn is centrally being driven by information technology.

"IT", Paul Wright contends, "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." [34] ICT tools, support, promote, and accelerate the innovation across the production phases of twenty-first century manufacturing: [35] ideation, design, prototyping, fabrication, supply chains, sustainability, and engineering services. He continues:

> "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."

Beginning from very different points of analysis, Paul Wright from engineering and Dan Breznitz from political economy, identify nearly identical phases in the Manufacturing Continuum and address them with parallel concepts. One wonders whether there is a technological basis for the production organization they observe or, alternately, whether the emerging social organization of production is itself shaping how the technology is evolving. [36]

We read in the press of truly radical innovations in production, all of which are really facilitated by or entangled with advanced computing. Additive manufacturing, colloquially known as 3D printing, has received the most attention, but it is not alone. Custom designed materials and nano-scale fabrication are other disruptive technologies in development. Will these emerging technologies add up to a dramatic break with past manufacturing practices, creating a new epoch, changing how market advantage is created? If so, when will that break come? [37]

It is still too soon to really know what direction these developments will take, who will be advantaged or disadvantaged, and when they are likely to have the greatest

impact. Consider 3D printing, which has become a buzz word and an image of a radically decentralized production future. “Make” magazine reviews the 3D printer machines under $3,000 that will best fit your project and sponsors Maker Faires that "celebrate arts, crafts, engineering, science projects and the Do-It-Yourself (DIY) mindset". This movement is often hyped as the cutting edge of a dramatically different industrial future. [38] Many say that these are mostly hobbyist projects, not yet, or perhaps ever real elements of a sustainable culture future. Some, pointing out that the original concepts emerged from research labs at major engineering schools, suggest that the sophistication of the tool sets, though largely now hobbyist machines, will grow and that the range of possible commercial consequences will expand. They can envision a world of craft-based industries. Others, to suggest the possibilities of this dramatically new future, will note that 3D printed parts are already being used in aircraft and space projects. Stuart Feldman notes that: “GE is planning to use additive manufacture to build the 85,000 nozzles needed for their next generation of jet engine. These nozzles need to operate at 2400C.” This isn't Maker Faire stuff. But current additive manufacturing tools are not fast enough or cheap enough. Consequently GE is investing in manufacturers to generate the new tools. “ [39] Similarly, Lockheed Martin is printing nosecones for satellite launchers, but the machine for that application costs close to one million dollars, well out of the reach of even most small businesses. [40]

For now, the range of materials used and applications of additive manufacturing in industrial scale production systems seem restricted by cost and characteristics of materials that can currently be deployed. In the next section we will see how the emergence of cloud computing platforms can make computation-intensive activities and access to sophisticated printing tools widely available on a pay-as-you-go basis.

The outcomes, the character of the production systems that emerge, will likely be powerfully shaped by the particular country or region that takes lead, the dyads of innovators and lead users. Again, let us return to the dyad of radical geographic redeployment of production across national boundaries and the possibility of dramatic reintegration of production. Will the rapid evolution of the technology across the phases of the production process entrench the decomposition into geographically and organizationally distinct phases? In the highly automated factories of the semiconductor industry, we saw the sharp separation of design from production – with firms like Cadence making the tools, and firms like TSMC (Taiwan Semiconductor Manufacturing Corporation) making the chips. The industry was thus separated into distinct segments of design, production, and tool development.

Conversely, will the rapid evolution of tools and materials lead to a reintegration of production in which design needs to take into account rapidly evolving choices of materials and processes? Henrik Glimstedt, staying within the electronics domain, presents a case in which Ericson begins to bring semiconductor production back in house precisely because separating design from fabrication was causing real problems in new product development.[41] GE reports the same logic in bringing production of some products back into the United States. In a slightly different vein, Toyota has begun its own internal development of batteries for hybrids. It is concerned about losing competitive advantage if it depends for batteries on its long time supplier.

Production and delivery platforms are again in flux, in part because of the evolution in electronics and ICT-enabled services and in part because of the radical developments in tools and materials. From that vantage, let us ask a question that Steve Cohen and I asked years ago. *Can you control what you can’t produce?* [42]

The Cloud accelerator[43]

The emergence of the next information technology platform, cloud computing, will accelerate both the ICT-enabled transformation of services and the revolution in manufacturing. Why will Cloud be such an accelerant?

Cloud computing will certainly make computation intensive resources widely available, not only to startups and small and medium sized businesses but also to smaller innovative groups within major companies. That means access to and the deployment of big data, design tools, prototyping, analytics for new materials, or just sophisticated logistics. Cloud will speed the development and deployment of new applications and tools.

What is Cloud? – Cloud Computing is not simply a story of geography. It is not just about where computing takes place, not just about whether the computing takes place in the Cloud, that is at a geographically distant or organizationally separate location, or on premises or at least within the company or agency's control. Cloud is, also, a story of architecture, a change in how computing is organized, and of implementation, how the new architectural concepts are put to work. We distinguish, thus, between *Cloud geography*, where the computing takes place, and *Cloud architecture*, what is done and how. The architecture and implementation of cloud computing is a basic change in the way of organizing ICT activities.

The consequences of this new computing platform, or dynamic utility, for our discussion of production can be understood by considering the *users* of cloud and the *providers* of cloud. For users, the barriers to entry for the use of computation intensive applications – from CAD and manufacturing processes through big data analytics – will drop. For users cloud can be considered a dynamic "utility" that makes computing resources widely and easily available. Most powerfully, ICT resources no longer need to be bought and maintained, but can be used as needed.

Jonathan Murray, Kenji Kushida, and I have written that:

> In laymen's terms: Cloud computing delivers the computing services to support business or personal needs without the user having to know how the underlying physical devices and software are configured or managed. ….Cloud computing delivers computing services - data storage, computation and networking - to users at the time, to the location and in the quantity they wish to consume, with costs based only on the amount of resource used. [44]

They are in that sense a form of utility, albeit an enhanced utility.

> As with a traditional utility, cloud-computing resources are always available, paid for according to the amount consumed and can be consumed in any quantity. (More precisely, there are contractual levels of availability and reliability.) Services are delivered through Internet connections, and the provider does not care about the device used to consume the service. Users do not care about how providers technically configure or operate the service on the backend as long as quality and price are acceptable, and users are free to use the resources as they see fit. [45]

For *providers*, by contrast, scale matters. Major providers are able to offer services and resources at much lower cost than most users can provide for themselves. Even for large users the appearance of infinite scalability is a great asset. Thus large users

may provision some functions internally and access public cloud resources for others. Who can provide cloud services competitively? Certainly the real gains from scale for the provider are likely to evolve over time, and the importance of marginal cost of computing for a user will vary by sector and application. That said, the major public providers are, for the moment, American. How much that matters is an important debate, but not one we need to address here.

Why Cloud matters – One consequence, as noted, is that the tools for the development of applications and the diffusion of computation-intensive applications will be faster and wider. The necessary computing resources will be available to "rent," meaning that the small player, or a project group in a larger company, need not buy the needed computing. The result is that computing can be moved from being a capital expense (CAP Ex) to an operating expense (Op Ex), bringing that computing into the realm of possibilities for many. Thus, for example, that advanced Computer Aided design, rapid prototyping, and sophisticated logistics will all be available to small firms and individual innovators. A second consequence is that Cloud architecture – by decoupling the development of applications from the evolution of the infrastructure – speeds time-to-value, the time from the conception of an ICT based innovation in services or manufacturing to the realization of value.

Why is cloud computing so radically new? Cloud computing architecture becomes possible because we have moved into an era in which computing resources, long scarce and expensive, are now widely available and inexpensive, a "Clouducopia" of computing, if you will.[46] The consequence of that abundance of resources is that computing can be done differently. Two terms can organize our thinking: "virtualization" and "abstraction". The ability to "virtualize" underlying hardware resources is the foundation for cloud computing. A user can run Microsoft Windows or Linux on a Mac computer along with the native OS X operating system. With Murray and Kushida, I have argued that "The Windows operating system or Linux is running in a "virtual" container, which emulates the hardware resources of a generic IBM PC….Physical infrastructure is decoupled from applications and platforms, which allocate computing, memory and storage resources without reference to underlying physical infrastructures." [47] The abundant availability of computing resources means that ""cycles", measure of computing resources, could not be wasted." [48] Consequently software was designed, optimized, to take advantage of particular hardware. We wrote:

> Oracle's success in database technology came through its ability to provide high levels of performance and scaling in resource-constrained environments. When those environments ran out of capacity, Oracle would be happy to sell you very expensive dedicated hardware solutions to overcome the problem. [49]

However, in a "cloud computing" environment, "the same problem can be overcome by scaling open source (free) database technologies over vast commodity hardware infrastructures."

A cloud architecture designed with abundant computing resources allows the infrastructure, the development tools, and the applications to be "abstracted". The "abstraction" separates the computing stack into "composable" parts. Applications and infrastructure are more loosely coupled. Tightly and rigidly arranged systems, systems in which applications that create value are tightly linked to the infrastructure on which they run, are difficult to adjust and adapt. The abstraction, the decoupling both creates flexibility in how resources can be deployed and makes many of the pieces of the system into lower cost commodities.

Let us reiterate the consequences. One is that scaling computing operations can be done with inexpensive commodity hardware running free open source software. One result, as we argued in "Clouducopia", is that the arms suppliers who sell proprietary hardware, optimizing computing resources, are now facing intense and new competition that for many is affecting their sales and profitability.[50] Second, the abstraction permits the three layers or functions of computing to be separated: the infrastructure on which system, the development tools to build functions and applications, and the applications themselves. Each can evolve with less attention to the others.
Again, in that sense Cloud Computing is just not a geography of where things are done, though that is the most popular understanding, but an architecture, implementation, and management model of how computing is done. We believe that firms are likely in years to come to choose to organize their own internal computing along Cloud principles. Therefore we are likely to see *private clouds* – run inside a single organization but on cloud principles; *public clouds* such as services offered by Google and Amazon, and *hybrid clouds* in which those with private clouds draw on public cloud resources. For now, the real consequence is that computation intensive tools for ICT-enabled services and manufacturing will be more widely available.

The Arguments Summarized

The transformation of production and its acceleration by cloud computing has been the focus of Part I. The arguments developed in that section are highlighted here.

- First, the transformation of production, including both manufacturing and ICT-enabled services should be our focus. The decomposition of production, moreover, further blurs the meaning of the distinction between services and manufacturing.

- Second, ICT-enabled services are as much a source of productivity, employment and growth as manufacturing. These services systems must be developed and built.

- Third, manufacturing is being pulled in two directions. On the one hand, the decomposition of manufacturing, and indeed of ICT-enabled services, has produced complex cross-national supply networks. In some countries, including the United States, that decomposition has decimated the core infrastructure of skills and knowhow required for competitive advantage in production. On the other hand, the rapid evolution of advanced manufacturing has encouraged the re-composition of production, the reintegration of development and production. Both processes will endure. A core question will be when a firm or place must control production to maintain a competitive position as products and technology evolve. A mosaic will result from strategy choices by firms and policy choices by "places". The question is when will manufacturing be a strategic asset and when a vulnerable commodity.

- Fourth, the transformation of production will be accelerated by the emergence of Cloud Computing as the next Information Technology platform.

Part II

Framing the policy debate: building on the past, imagining the future [51]

The way out of the commodity trap for wealthy countries, as we said at the beginning, is to generate new and innovative approaches to value creation and production, developing distinctive high value added products, services and goods, as well as creating distinctive defensible positions in the production and distribution of lower margin more commodity like products. Remember we know that that Luddites lost their jobs but that the economy became richer and later generations prospered. The debate has posed itself over and over. Economies keep growing and median incomes, unequally, certainly, have continued to rise. It is easier to identify the jobs that are destroyed, to identify the "Race against the Machine,"[52] than to imagine the ways new jobs will be created. Of course, the character and location of those jobs may advantage some communities and disadvantage others.

The classic policy nostrums are inadequate, or certainly not adequately specified. Consider two classic categories: infrastructure and skills. What sorts of infrastructure beyond roads and bridges are required for a digital era? What access and what tools are needed, and by whom? What types of skills should be developed, for whom and how? And trade protection in its diverse forms, certainly in an era of largely open trade, decomposed production, and ICT-enabled services will have limited positive effect. Can we go further than the classic?

What does our analysis to this point suggest is required?

The way out: thoughts on policy tools

The Tools – First, focus on tools. Building and effectively applying the tools for the next era of production, both the ICT-enabled transformation of services and the ICT - facilitated manufacturing revolution, is central. Note, and forgive the repetition, that it is essential both to develop next generation of tools and to effectively diffuse and apply them. The array of tools from 3d printing, new design tools, and big data analytics through ICT platforms with new architecture such as cloud evolve very rapidly. Indeed, the pace of digital technology development influences the pace of tool development in the economy as a whole. Certainly that creates possibilities, but for firms large and small it represents a challenge to understand and strategically implement the new tools.

Why the emphasis on tools? We know that these tools do two things: 1) They automate the routine, substituting capital for labor, eliminating many jobs; 2) They generate new technical possibilities for processes and for products -- services, physical goods, and integrated systems, perhaps even allowing entirely new production system. Jobs will be generated building the tools and the new processes and products they permit will likewise generate employment and productivity.

Who will be the next generation toolmakers? Will they emerge from those who have a mastery of the underlying digital technology and learn to move forward make practical applications of the technology? Will the new tools come from the technology community? Or, conversely, will those who now know industrial processes and

material in manufacturing, or retail businesses for service applications, reach backward into the pool of emerging technologies and craft new approaches? Will the new tools build on existing industrial know-how? At the risk of a cliché, will Silicon Valley geeks or German and Italian tooling companies be the tool makers of the next era? Most likely, both, but they will succeed very differently.

The possibilities of these new tools, for both services and manufacturing, are evolving so rapidly that policies to assure the tools are absorbed and applied are essential. Can we, once again, go beyond the ordinary litany? The traditional list is evident, but specifying its particulars is difficult: Infrastructure in the form of widespread ICT access; Training and education to assure that companies and workers alike have the capabilities to apply the new possibilities; R & D aimed developing at assuring that the community can participate in the cutting edge of developments. The challenge will be to package the infrastructure, training and R & D in ways that link them into the existing community of producers while at the same time allowing new firms with new approaches to grow and prosper. There are models in many countries from Japanese machine tool centers, the American agricultural extension services, the Danish Technology Institute, German Fraunhofer Institute. Elsewhere, Jonathan Murray and I have proposed the creation of Cloud Development Centers that would both provide the foundation for tool development, encouraged applications addressing the needs of local communities as a stepping stone to broader markets, and help the local community to stay abreast of global developments. The notion addresses both the development issues and concerns about privacy and security in the Cloud.

Decomposition and reintegration: is there policy for both? – We noted a tension between decomposition and reintegration of production. From a policy vantage, do we have to choose, and if so, how do we choose? Let us return to the reorganization of production around phases of production rather than sectors, as discussed in Part I. The policy implication is a focus on the capabilities and competencies required in each phase. "Innovation" comes at each phase of manufacturing and development of ICT enabled services. [53] It will look different in each phase and require distinct competencies and distinct policies. [54] Specialization in the phases of production of a "place" – country, region, or locale – turns on the package of competencies and policies. [55] Communities will need to consider which distinct competencies are essential for the phase of production in which they are likely to specialize.. [56]

A list of competency domains would be quite long; these instances are meant simply as examples.

- A first competency domain is *product creation*. This is really a set of competencies beginning with conception, definition, and design. We emphasize that there is a major difference between the ability to come up with a new product altogether and the ability to define it and design it.
- A second competency domain is in *production engineering*, including 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. There is a radical difference between the lean production model of Japan or the volume models of Korea and the high quality low volume expertise noted in Denmark.
- A third competency domain is *innovation in the underlying components and constituent elements of products*, that is, integrating science and technology advances. This may be innovation in screen technology or micro processor design, or the production technology for semi-conductors. Each module, each unbundled process, is a marketplace target for innovation.[57]

- Other competency domains would include branding or product design and layout.

Conversely, if the manufacturing itself begins to be reintegrated, or if a radical new production system begins to unfold, then a new set of competencies for *the analysis of integrated production* may be called for. In sum, faced with reintegrating production advanced manufacturing will need to define a new domain that integrates these several competencies and loosely speaking create an integrated field of Production Sciences.

Direct government action – Finally, can governments act proactively to promote directly the location of production of goods and services? Conventionally, in this global era we are told that conventional policies of promotion and direct subsidy to firms will, apart from legal challenges, have limited affect. Building on our analysis to this point, there are two related ways of approaching this.

One approach, building on the logic of Dani Rodrik, would initially ask what changes in the business environment or tool set, or conditions of production, if they were possible, would significantly alter the competitive position of firms in a particular "place". The discussion would then focus on whether the radical evolution of tools and infrastructure would permit such a dramatic shift. [58] The government as convener and broker could help identify both opportunities for private investment and for government policy and investment.

There is a second, more direct approach. We must begin by distinguishing amongst "platforms", "eco-systems", and "clusters" "*Platforms*", for our purposes, are the sets of framing technologies on which products are developed. Cloud is a platform for next generation Information Technology will be based. But the notion, of course, is not limited to ICT. Automobiles and aircraft likewise rest on "platforms" within which suppliers must operate. Importantly many of the platforms are global in character, resting on defacto and formal standards. *Global "eco-systems"*, as we will use the term here, constitute the networks, the webs if you will, of constituent elements needed to build goods and services on any of these platforms. Precisely because the tools, the components, and indeed the know-how are dispersed globally in most cases, the beneficiaries of direct subsidy or protection will hard to determine, often outside the jurisdiction of a particular government. Within these global eco-systems we certainly find *"local clusters"* of competency and skill. Those local "clusters" of activities are part of the global eco-system. Policy must build its clusters, assuring they find their distinctive position in global eco-systems. But, so far, that is not saying more than, as we noted, government focus on the particular phases in which a "place" -- be it region, nation, or city -- is developing expertise and position. Can we go further? What can a government do to make its local clusters a vibrant point in global eco-systems, developing and contributing to globally significant platforms?

Governments in the pursuit of their ongoing responsibilities ---- health care, energy efficiency, providing roads and bridges as examples, can they as lead users be agents of next generation innovation. Can they define policy objectives that permit the definition and emergence of platforms around which global ecosystems may evolve. If so they may both build and invest in local clusters of competency while drawing in waves of innovation. But they must be conscious of the role.[59]

Finally, I would emphasize what Breznitz, Nielsen, and I have argued years ago. There are no magic strategy bullets in this era of networks, production decomposition, and

the services transformation. Rather there are an array of options and choices. Noting that, we wrote that:

> The Irish build by accumulating competencies from a portfolio of MNCs off-shoring into Ireland. The Israelis invest diversely in support of novel product innovation in advanced technology. The Finns have established national institutions to harvest technology from around the world, developing a distinctive capacity to identify crucial technology developments wherever they are occurring. They then make the public and private investments in the internal competencies that are required to effectively integrate in Finland the technologies they harvest abroad. The Danes have developed networks of small and medium sized firms, and armed them through public investments in training and institutes with competencies in several domains from design to technology. Taiwan through policies that institutionalize a unique division of labor between public research institutions and private companies has made heavy investments in both production engineering and product creation. Those investments contributed to a profound restructuring of the semiconductor industry that has seen much of firm design, development and marketing separated from production.[60]

Strategy choices, we argued, emerge from two complementary perspectives. One perspective, building from the past, asks how existing community resources can be deployed and redeployed in new market and technology circumstances.

> This analysis begins by identifying, mapping, existing competencies and clusters of firms and activities. It then consider how these competencies and clusters can be oriented, recombined, reposition, supplemented and complemented to be the foundation of value creating activities. The Swiss watch-making districts self consciously asked where their special array of skills could be redeployed. The Danes asked how their tradition of local networks and collaborations could once again be a foundation of competitive advantage.[61]

A second perspective, imagining the future, seeks to envision and generate radical new trajectories of growth. We wrote that though this strategy does not build from a completely blank slate, new directions certainly require generating new competencies and establishing new infrastructural capabilities. There are clear stories of places – nations, regions, and communities – levering themselves onto new trajectories. Narrowly, the establishment of the UCSD campus of the University of California is one such example. The reorientation of the Finnish economy away from the Soviet Empire and mid level technologies toward Western markets and more advanced technologies is another.

The ongoing challenge for the advanced industrial democracies, we argued as we began, is to expand the real income of the citizens, to sustain growth in employment and productivity. To do so, we said, their economies will have to escape from the Commodity Trap. To do that, to escape the commodity trap, the task is to imagine policies and institutions that will link the foundations of the past to the possibilities of the future. Hence, we must build on the past while imagining the future.

Framing the Policy Debate

Before concluding, there are two issues that need to be noted in policy discussions of how to escape the commodity trap, policy debates about production generally and manufacturing specifically. The first is that production is simultaneously a strategic asset and a vulnerable commodity. The second is that it is entirely unclear whether this production transformation is truly a revolution or simply an evolution.

Strategic asset or vulnerable commodity? If manufacturing specifically, or production more generally, are simply low wage sinkholes, then perhaps they can be dispensed with. If, by contrast, production is essential to competitive advantage and innovation, then it is a strategic asset that ought be defended. The policy problem, a matter both of formulating correct policy and responding to political pressures, is that the answer is continuously changing.

Manufacturing in a digital era, for companies and countries, can be either a strategic asset or a vulnerable commodity. A few years ago I wrote:

> For companies the question is: "When can production serve to generate and maintain advantage? Under what circumstances is the lack of in-house world class manufacturing skills a strategic vulnerability? When is it simpler and easier to just buy production as a commodity service? For the nation, 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? [62]

There will not be a single answer to question of whether you can control what you can't produce, but rather answers that are specific to particular industries and perhaps to specific strategies in particular places.

Let us choose the case of sectors, products, or product segments emerging based on new processes and new materials. An emerging sector such as nanotechnology is all about how you make things. Biotechnology, likewise, is about how you make things. In these sectors the question of production, product innovation, value creation, and market control remain entangled.

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 the significant players in the market? Or will established players in pharmaceuticals and materials absorb the science and science based engineering knowledge and techniques, by purchase of firms that have spun out from a university or alternately by parallel internal development by employees hired from those same universities? There is an on-going, critical interaction among: 1) the emerging science-based engineering principles; 2) the re-conceived production tasks; and 3) 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. Those intimate interplays have traditionally required face-to-face, and hence local and regional, groupings. With the new tools of communication, what happens to the geography of the innovation node is an open question. Can a firm capture the learning from that interplay if it outsources significant production?

For the firm, the question is whether that interaction is more effective, the learning captured, within the firm. Firms must ask whether that interaction, and the learning it generates, possible at all through arms-length marketplaces? As new processes or materials emerge, it is harder to find the requisite manufacturing skills as a commodity. Certainly, with new process and materials, new kinds of production skills

become essential. Will outsourcing risk transferring core product/process knowledge, allowing competitors to develop strategically critical assets? Those intimate interplays have traditionally required face-to-face, and hence local and regional, groupings. With the new tools of communication, what happens to the geography of the innovation node is an open question.
Again, it is evident that there are cases when if a firm, or a national sector, loses the ability to know how to make things, to use production as a strategic capacity, then it will lose the ability to capture value. Whatever goes on in the labs at Berkeley, if you can't capture it in a product you can make and defend, then the science is not going to translate into a defensible position in terms of jobs and production. When do the new tools alter fundamentally the underlying business models on which firms operate? Identifying those cases is difficult. The risk is not the promotion and development of new sectors, but protection and dampening of competition in the old.

There will be an enduring tension between the pressures reinforcing the commodity trap for the advanced countries, the decomposition and relocation of production, and the tools to escape the trap, that include new sources of value creation with ICT-enabled services and the reintegration of manufacturing. There will not be a single core solution, but a diverse mosaic of outcomes. And we are only at the beginning.

Production: evolution or revolution?[63] Escaping the commodity trap is pressing and urgent. Escape requires capturing the possibilities of the production transformation depicted here. Will the 21st Century world of production and the economy in which it is embedded be an evolutionary extension of what we know, or a radically new era? For what world must policymakers prepare?

Thomas Edison would recognize today's electricity system. Will the emerging production system be, likewise, a recognizable extension of the existing system, or something radically different? Services, we know are already being transformed by ICT tools, by the algorithmic revolution. That transformation will continue apace. By contrast, the existing manufacturing system, for the next five to ten years or so, is likely to be advanced but not transformed by the set of ICT innovations we have discussed. Manufacturing jobs will be in spread in different places, and the work will require different skills; corporate and regional winners and losers will be reshuffled. The effective development and application of ICT based tools will be central, but how they are applied will likely for now reflect existing approaches to manufacturing.
But what comes after the next 10 years? The transformation in the production of services and the revolution in manufacturing will each proceed, and the two will become entangled and reinforce each other. Will manufacturing from design through distribution end up being profoundly decentralized, looking more like the Internet era of data communication than the AT&T era of centralized voice networks?[64] Or, as with a sequence of Information innovations from radio through television through the Internet, will we see moments of creativity and innovation followed by chokeholds established in the new production system that then give power to a handful of dominant players. Microsoft dominated in the era of the PC, while Google and Facebook are winners in the era of the incipient cloud.
Will policy fights, such a net neutrality, end up favoring those who own the "pipes" of the internet – and that includes both network providers and Google – or those who put content into the system and innovate on its edges? Certainly the traditional economies of scope and scale favor concentration of production and distribution in the hands of a few players, while the widespread diffusion of computing capacity, open source technologies, and the individuation that 3D printing may permit new comers to the discomfiture of established players.

Will the widespread distribution of tools mean that a variety of distinctive regional or national systems can be built, or will a new dominant production paradigm establish itself? It is essential to emphasize, again, that how technologies are used, and the production systems which result, are not dictated by the technological possibilities themselves. Rather the outcomes are functions of policies and corporate choices and vary between communities and indeed within communities. Technologies represent a set of ingredients that influence what may be possible. Or to choose a related metaphor, they may represent a set of recipe choices. The recipe books may evolve. Machine tool industries in the United States, Europe and Japan in the 1990s differed in part because the machines were designed to different approaches to manufacturing. Likewise early production applications of ICT were radically different. One American producer speculated on using animated cartoons for worker training because of the limited literacy of the particular workforce at the same time that an Italian tool maker had created a simple user interface on top of a C++ built system to permit shop floor worker control and innovation. Since the new tools will be applied successfully and competitively in diverse ways, existing national differences are likely to endure. There may not be a single race to a 21st century digital and production victory, but a variety of winners.

One optic focuses on the character of employment and skills. Some things are evident. Routine activities will be increasingly vulnerable to automation. Inexpensive labor is not always an alternative to automation; as the precision and powerful possibilities of ICT tools in both services and manufacturing make capital investment rather than labor savings all the more important. Robots already paint automobiles for the precision and health and safety advantages they provide, and ICT systems already underpin product design and conception. In the next years some of the more radical technologies such as additive manufacturing system (3D Printing) and custom materials will begin to reshape the fabric of manufacturing, recast the phases of production we considered earlier.

Here is the real question. Will that increasing automation of the routine, the need for precision, and complex new materials so strip out employment that we create a new underclass? If so, perhaps that underclass would look like one in Kurt Vonneguts first novel, Player Piano, in which employment is a privilege of the upper class but the huge wealth of the production system creates a consumption rich underclass. Might the new production system look like a modern version of the servants era of the BBC series, Downton Abbey, in which a wealthy Elite lives upstairs served by a servant underclass?

Or, might we hope for a broadly productive economy with employment and real income steadily growing. If automation is replacing routine work, we must then ask, who builds the tools? Who creates the games and on line service applications? Will efforts at education and training succeed in creating a new era of entrepreneurs and tool makers? We know that analytic skills and the ability to communicate complex information will be critical, quite apart from entrepreneurship and creativity. Will there be enough jobs in these new functions to offset those lost to ICT enabled automation of services and manufacturing? Where in the end, in increasingly global labor markets, will those jobs locate? And, even if the jobs require skills and training, if there are enough workers clamoring for them, wages may not rise with productivity. Indeed, if there is an enormous abundance of “entrepreneurs”, they too may end up being a new working class.[65] Since we do not really know which assumptions will hold true, we cannot effectively model the future labor markets.

We can tell rival stories, but for now they are just that: stories about utopias and dystopias. The outcomes, both the character and the consequences of the evolving or revolutionary production system that emerge from efforts to escape the commodity trap, will turn on policy choices of government and strategic decisions of firms. The crucial policy question is how to nudge that transformation in the advanced countries toward higher value added, higher skilled, higher wage solutions.

Endnotes:

[1] The group of us has been working together on related projects for a number of years and produced a variety of co-authored articles.

- Dan Breznitz: Professor, Munk School and Department of Political Science, University of Toronto
- Stuart Feldman: Vice President of Engineering, Google
- Kenji Kushida; Takahashi Research Associate in Japanese Studies, Shorenstein Asia Pacific Research Center, Stanford University
- Jonathan Murray: Executive Vice President and Chief Technology Officer, Warner Music Corporation
- Niels Christian Nielsen: Board member of diverse companies from Development Alternatives International and Prophet Corporation in the United States through Unimerco and Quantum in Denmark.
- Paul Wright, Professor, Department of Engineering, University of California, Berkeley, Director of CITRIS (Center for Information Technology in the Interests of Society) Director, BECI (Berkeley Energy and Climate Institute)

The research includes work on cloud computing, the ICT enabled service transformation, regional development, and 21st century manufacturing. The particular articles are separately cited throughout the essay.

[2] This framing is drawn from: John Zysman, Niels Christian Nielsen, Dan Breznitz, with Derek Wong. "Building on the Past, Imagining the Future: Competency Based Growth Strategies in a Global Digital Age." BRIE Working Paper 181, October 2007. http://brie.berkeley.edu/publications/WP181.pdf

[3] John Zysman, Stuart Feldman, Kenji E. Kushida, Jonathan Murray, and Niels Christian Nielsen. "Services with Everything: The ICT-Enabled Digital Transformation of Services." *The Third Globalization? Can Wealthy Nations Stay Rich in the Twenty-first Century?* Dan Breznitz and John Zysman (Eds.) Oxford University Press, 2013.

See also, Zysman, John, Dan Breznitz, Martin Kenney, and Paul Wright; *21st Century Manufacturing*, published by UNIDO in 2013. Chapter 3. pp 15

"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."

[4] See Dan Breznitz, *Innovation and the State*. Yale University Press, 2007.
Dan Breznitz and Michael Murphree. *Run of the Red Queen*. *Innovation, Globalization and Economic Growth in China.* Yale University Press, 2011.

[5] "Services with Everything" The title of this section is borrowed from the article "Services with Everything" . The section on services is drawn from work done jointly on that article with Jonathan Murray, Stu Feldman, Niels Christian Nielsen, and Kenji Kushida. It also draws on much earlier work with Stephen Cohen: Cohen, Steven. *Manufacturing Matters: The Myth of the Post Industrial Economy.* Basic Books 1987. Other work drawn on for this section includes:

- Kenji Kushida, Jonathan Murray, John Zysman. "Diffusing the Cloud: Cloud Computing and Implications for Public Policy." *Journal of Industry, Competition and Trade,* Sep 2011.
- Kenji Kushida, Jonathan Murray, and John Zysman "The Gathering Storm: Analyzing the Cloud Computing Ecosystem and Implications for Public Policy." Digiworld *Economic Journal*, *Communications and Strategies* 85.1 (2012): 63.
- John Zysman, Jonathan Murray, and Kenji Kushida. *Cloudocopia, Into an Era of Abundance.* CLSA University, Credit Agriculture Securities, 2013.
- Niels Christian Nielsen, Jonathan Murray, and John Zysman. *The Services Dilemma: Productivity Sinkhole or Commoditization.* Copenhagen: Sats: Rosendahls – BookPartnerMedia, 2013.

[6] John Zysman, "The 4th Service Transformation: The Algorithmic Revolution." *Communications of the Association for Computing Machinery Special Issue on Services Sciences, 48* (2006).

[7] By now we can all recite the examples; bank ATMs have automated simplified bank transactions, and consumers increasingly book airline tickets and car rentals online. In major enterprises, payroll processes have been reorganized and largely automated.

[8] Nordhaus, William D. "The Progress of Computing." Working Paper. Version 5.2.2 Yale University Press and NBER (2002).

[9] Michael Borrus and Francois Bar led a remarkable cross national study of the early uses of network technology. The comparative project examined 25 firms in five sectors and in 5 countries.

Borrus, Michael and Francois. "From Public Access to Private Connections: Network Policy and National Advantage" BRIE Working Paper 28, September 1987. http://brie.berkeley.edu/publications/wp%2028.pdf.

[10] Thanks to Mark Huberty for this insight, and for lending the language.

[11] Op Cit. Zysman et al., "Services With Everything." This section draws heavily from the joint work with Stuart Feldman, Jonathan Murray, and Niels Christian Nielsen.

[12] Of course 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.

[13] The underlying productivity data was developed by Bart Watson. The data is now dated. We have every reason to assume the trends there are being continued.

Watson, Bart. "Nations of Retailers: The Comparative Political Economy of Retail Trade." Phd. Dissertation Political Science University of California Berkeley, 2011.

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 1.

Table 1. Productivity Increases, United States (1995–2003), Selected 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.

[14] Kenji Kushida made a major contribution in effectively formulating and presenting this material as part of the joint work, noted before, with Feldman, Murray, Nielsen and Zysman

[15] Kenji E. Kushida, "Leading without Followers: How Politics and Market Dynamics Trapped Innovations in Japan's Domestic 'Galapagos' Telecommunications Sector." Journal of Industry, Competition and Trade 11, no. 3 (2011): 279-307. 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.

[16] This section is drawn from private conversations and articles in Wikipedia. The phrase of the internet of things is attributed to Kevin Ashton. The underlying concept is often attributed to Bill Joy.

[17] Many thanks to Erkki Ormala then with Nokia who first made this argument to me at a lunch in Helsinki.

[18] Stephen Cohen and John Zysman. *Manufacturing Matters: The Myth of the Post-Industrial Economy,* New York: Basic Books, 1987.

[19] I developed this point at length in: John Zysman, "Strategic Asset or Vulnerable Commodity? Manufacturing in a Digital Era.*" New Directions in Manufacturing:* Report of a Workshop, Committee on New Directions in Manufacturing, Board on Manufacturing and Engineering Design, Division on Engineering and Physical Science. Washington, DC: National Academies Press, 2004. http://brie.berkeley.edu/publications/WP147.pdf.
Presented in March, 2003 at the "New Directions in Manufacturing," the 2003 Forum for the National Academies of Science.

> "….let us consider why there was an enduring confusion about the supposed transition from industry to services. The overall notion is that manufacturing as a portion of the economy had dropped precipitously and the portion included in the category services had risen. The precise numbers depend on what is counted and how. The conventional categories show private goods producing industries in the US declining toward 20%. Durable goods manufacturing fell below 8%. Private service producing industries have risen over 67%. Depending on how government is counted in (some would argue that no government expenditures are services) will determine the precise balance of services in the economy as a whole."
>
> As we disassemble the numbers, the notion of the overwhelming importance of a "service" economy replacing an industrial economy will slowly dissipate. Let us consider the steps in the process.
>
> Let us separate business services from personal and social services. In the category of personal/social services we would put teachers and prison guards. Cynically put, personal and social services includes a whole series of caretakers, including valets in the old British days.
> Then, let us divide business services, the remainder, into two categories; those activities upstream from production and those downstream from the point of production. What is the difference between downstream and upstream services? Go to an auto mall near where you live and look for a car. In many cases the same auto dealer structure will sell you a Ford or a Lexus. The dealer

is downstream from production and doesn't depend on where the product was made. The downstream activity is not linked to where the good is manufactured. The dealer certainly does not care where the car was made, whether the Ford was produced in Brazil or Michigan, or the Toyota in Japan or the United States.

By contrast, the upstream activities are the ones going into manufacturing, supporting the production activities. The question is how tightly linked the services are to the manufacturing operation; whether they can be separated from the production and moved elsewhere. Those that cannot be moved are tightly linked; those that can be separated are loosely linked. There are the activities on the production line, things we obviously call manufacturing. There are services that go into that production line activity. There are ancillary activities such as window washing and those that are supportive such as back office activities or customer relation phone services.

There are two points that need noting as we disassemble these categories. First, consider the statistics. If the window washer, or phone service personnel, or billing service personnel work for General Motors, then those folks are manufacturing sector employees. If they work for Ace Window Washers, Back Office Temp Services, or Phone Service Outsourcing, then they are service sector employees. Whatever the firm, the employees are engaged in the same activities; but they fall in different statistical categories. So the statistic, services, is a confused measure that blurs what is being done, the activity, with legally where it is being done, its corporate location.

Next, consider the tightness of the linkages between the services and the underlying manufacturing activity. If General Motors moves to Brazil the window washers won't go with it. The Detroit window washer cannot wash windows in a Toyota plant in Japan. On the other hand many back office services can now be performed overseas. The back office activities and the customer support services are much more mobile than window washing; window washing is locationally tied. Even before the manufacturing moved to Brazil, the back office might have moved to South Dakota and the phone services to Bangalore.

Hence we must ask, what links these activities together? What strengthens or weakens these linkages. For this discussion, the question is the distinction between strong and weak locational and organizational linkages, which activities must geographically or organizationally stay together. And what is the glue that binds them? Indeed, in a digital era with easy communications, including data document transfer, these various back office and customer support services become even more mobile. Is a mastery of English and a sophisticated telecom infrastructure with global links, even if it has limited local ties, is all that is needed? Certainly, the ability to communicate fluidly and collaboratively over distances loosens the locational linkages, alters appropriate organizational structure, and changes control structures amongst other kinds of activities, as a distributed system of open source software development suggests.

In summary, we were never moving in any simple way from manufacturing into services. ….

[20] Op. cit. Zysman *Et al. 21st Century Manufacturing*. Unido, 2013. This section draws on the work prepared for UNIDO. It draws particularly on the sections by Dan Breznitz, by Martin Kenney, and by Paul Wright.

[21] Suzanne Berger does precisely this in the excellent book: Berger, Suzanne with the MICT Task Force on Production in the Innovation Economy. *Making in America: From Innovation to Market*. Cambridge, MA: MICT Press, 2013.

[22] Roger Bohn and Ramchandran Jaikumar, "From Filing and Fitting to Flexible Manufacturing: A Study in the Evolution of Process Control." *Foundations and Trends in Technology, Information, and Operations Management.* Now Publishers (2005).

[23] The literature on this is vast. See for example Womack, James P, Daniel T. Jones, and Daniel Roos. *The Machine That Changed the World: The Story of Lean Production – Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry.* New York: Free Press, 1990.

My account of how "Lean" came about is in article written with Laura Tyson. Tyson, Laura and John Zysman "The Politics of Productivity: Developmental Strategy and Production Innovation in Japan," in Johnson, Chalmers, Laura d'Andrea Tyson and John Zysman. (1991). *Politics and Productivity: How Japan's Development Strategy Works*. HarperCollins Publishers: New York, NY.

[24] Laura Tyson and I make this case in the article noted above.

[25] Op Cit.Suzanne Berger, *Making in America*.

[26] The same tension, of course, exists in the history of network technologies themselves. And today large players, new comers such as Google and Facebook, and established network providers such as ATT and France Telecome– albeit with very different objectives – struggle to control and shape the system. See Timothy Wu *The Master Switch; The Rise and Fall of Information Empires*. Vintage Books 2010

While we can tell stories, competing stories really of what the future may look like, we cannot answer the question of what a new paradigm will look like or what the mosaic of outcomes will be. Throughout, we emphasize that the outcomes are not dictated by the technology, but by public policy and firm strategy choices that shape how the technology is deployed.

[27] This section draws directly on the work of Dan Breznitz. Breznitz develops this argument in several places. The fullest argument is in D. Breznitz & M. Murphree, *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China* (New Haven: Yale University Press, 2011); Breznitz also develops the argument in 21st Century Manufacturing Prepared for UNIDO. United National Industrial Development Organization Ed. John Zysman 2012; The same argument is found, and much of this material is taken from "Facing the Double Bind: Maintaining a Healthy and Wealthy Economy in the Twenty-first Century" John Zysman and Dan Breznitz, the introduction to *The Third Globalization: Can Wealthy Countries Stay Rich Ed.* Breznitz, Dan and John Zysman, Oxford University Press 2013.

[28] On container shipping, there is an excellent readable presentation. *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger,* Marc Levinson Princeton University Press 2006

[29] Breznitz, Dan pp 92 Chapter 4 "The Problem of Decomposition: Industrial Policy and Growth in a World of Phased Production" in Op Cit. 21st Century Manufacturing Zysman et al. See also D. Breznitz, Innovation *and the State: Political Choice and Strategies for Growth in Israel, Taiwan and Ireland* (New Haven: Yale University Press, 2007).

[30] Ibid. pp 92

[31] Ibid. pp 92

[32] John Zysman and Dan Breznitz "Introduction. Facing the Double Bind: Maintaining a Healthy and Wealthy Economy in the Twenty-first Century " . Op Cit. Zysman and Breznitz, *The Third Globalization,* Pp 30.

[33] Op Cit. Kenney, Martin "Where is the Value in Value Networks" in *21st Century Manufacturing*, Zysman Ed.

[34] Ibid. Wright, Paul. "Manufacturing Metropolises: Design Fabrication and Service." *21st Century Manufacturing.* Zysman Ed. Vienna: UNIDO, 2013. http://www.unido.org/fileadmin/user_media/Services/PSD/21_Century_Manufacturing_UNIDO_2013.pdf
Note: Paul Wright has a separate engineering volume on these topics: Wright, Paul. *21st Century Manufacturing*. Prentice Hall, 2000.

[35] Language adapted from Paul Wright. Wright, Paul. "Manufacturing Metropolises: Design Fabrication and Service."

[36] I would iterate that the use of technologies is not dictated by the technological possibilities themselves. Machine tool industries in the United States, Europe and Japan in the 1990s differed in part because the machines were designed to different approaches to manufacturing. Likewise early applications of ICT were radically different. One American producer speculated on using animated cartoons for worker training because of the limited literacy of the particular workforce at the same time that an Italian tool maker had created a simple user interface on top of a C++ built system to permit shop floor worker control and innovation.

[37] The institute for Defense Analyses projects truly radical changes when we look a decade out. See Shipp, Stephanie S, Nayanee Bhavya Gupta, Lal, Justin A. Scott, Christopher L. Weber, Michael S. Finnin, Meredith Blake,Sherrica Newsome, and Samuel Thomas. *Emerging Global Trends in Advanced Manufacturing*., Project Leader. Washington, DC: Institute for Defense Analyses, March 2012.

[38] Hatch, Mark. *The Maker Movement Manifesto.* New York: McGraw Hill Education, 2014

[39] Tim Catts, "Printing Engine Fuel Nozzles Propels $6 Billion Market." *Business Week GE,* November 12, 2013. Web. http://www.businessweek.com/news/2013-11-12/ge-printing-engine-fuel-nozzles-propels-6-billion-market-tech

[40] Private conversations with Lockheed representatives

[41] Private conversation and unpublished articles

[42] Op. Cit; Cohen and Zysman, *Manufacturing Matters.*

[43] This section is drawn from work done by Jonathan Murray, Kenji Kushida, and myself. There are three principal pieces.
1. The most recent is: Zysman, John, Jonathan Murray, and Kenji Kushida. "Clouducopia: Into the era of abundance." CLSA University, January 2013. Web. www.clsau.com.
2. "Diffusing the Cloud: Cloud Computing and Implications for Public Policy", Kenji Kushida, Jonathan Murray, and John Zysman in the *Journal of Industrial Competition and Trade* released June 3, 2011
3. Kushida, Kenji, Jonathan Murray, and John Zysman. *"The Gathering Storm: Analyzing the Cloud Computing Ecosystem and Implications for Public Policy." Communications and Strategies,* March 2012.
For up to date discussion of these issues see Jonathan Murray's Blog: www.adamalthus.com/

[44] Op Cit. Kushida, et. al. "Diffusing the Cloud", pp 3.

[45] Ibid. pp 5.

[46] Op. Cit. "Clouducopia: Into the Era of Abundance".

[47] Ibid. pp 9

[48] Ibid. pp 9

[49] Ibid pp 10

[50] Op Cit. Kushida et al. "Diffusing the Cloud"

[51] This label and subtitle are drawn from op cit: Zysman. et al. "Building on the Past, Imagining the Future: Competency Based Growth Strategies in a Global Digital Age." 2007

[52] Brynjolfsson, Erik and Andre McAfee, 2011. Copyright by the authors, *Race Against the Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy*

[53] Breznitz emphasizes this point in the two books previously cited. Op. Cit. Breznitz, *Run of the Red Queen.* Breznitz, *Innovation and the State.*

[54] Op Cit. Zysman. et al. "Building on the Past, Imagining the Future: Competency Based Growth Strategies in a Global Digital Age." 2007

[55] Op. Cit. Breznitz.

[56] This material is drawn from: Op cit. John Zysman, Niels Christian Nielsen, Dan Breznitz, with Derek Wong "Building on the Past, Imagining the Future: Competency Based Growth Strategies in a Global Digital Age".

[57] Ibid.

[58] Rodrik, Dani. "Industrial Policy for the Twenty First Century." Vienna: UNIDO September 2004.

[59] Intellectual Ventures concept of mega projects is a version of this approach. How to define this goals, arrange the project, is a daunting undertaking.

[60] Op. Cit. Zysman et. al. "Building on the Past," 2007.

[61] Ibid.

[62] Op Cit. Zysman, John. "Strategic Asset or Vulnerable Commodity? Manufacturing in a Digital Era."

[63] Op Cit. Shipp, et al. Institute for Defense Analysis. *Emerging Global Trends in Advanced Manufacturing.*

[64] Op Cit. Berger, *Making in America*. Berger, for the sake of discussion, postulates a highly decentralized production system.

[65] Venkatesh Rao. "Entrepreneurs are the New Labor." *Forbes,* September 3, 2012.

The emerging transformation of the production of goods and services is dramatically altering what is produced, where, how, and who captures the value. It creates opportunities and challenges. Part I of this essay examines the transformation of production and its acceleration by Cloud Computing. A first argument is that the transformation of production, including both manufacturing and ICT-enabled services should be our focus. A second argument is that ICT enabled services are a source of distinct value in the economy. Third, it considers the distinct and contradictory challenges facing manufacturing. The fourth argument is that the transformation of production will be accelerated by the emergence of Cloud Computing as the next Information Technology Platform. Part II of the essay makes a few focused policy suggestions and considers several issues policy makers need to consider as they frame policy. The emphasis is on the role of next generation tools and competencies of “places”. The crucial policy question is how to nudge that transformation in the advanced countries toward higher value added, higher skilled, higher wage solutions.