Production In A Digital Era:
Commodity or Strategic Weapon?

© John Zysman
BRIE

Working Paper 147
September 2002

Section I summarizes and recasts an argument made with Stephen Cohen: Manufacturing Matters: The Myth of the Post –Industrial Economy Basic (1987)
Section III summarizes and is drawn from two essays written with Michael Borrus;
"Globalism with Borders: The Rise of Wintelism as the Future of Industrial Competition." Industry and Innovation Vol. 4, No. 2, Winter 1997.
"You Don't have to Be A Giant: How The Changing Terms of Competition in Global Markets are Creating New Possibilities For Danish Companies" Michael Borrus and John Zysman. Working Paper 96A at BRIE, February 1997. Available at http://brie.berkeley.edu/~briewww/
Section IV grew from conversations with Steven Weber as part of a joint article "The Political Economy of the Digital Era" and insights from Weber's forthcoming book: The Success of Open Source forthcoming, Harvard University Press, 2003

Executive Summary

The rise of the digital economy reignites debates over the transformation of production in industrial economies. For several decades, analysts attempted to describe the central features of the next economic epoch with labels like the knowledge, information, or service economy. The conventional argument claimed that just as an agricultural economy gave way to a manufacturing economy, an industrial economy was giving way to a service economy. Hence, their arguments went, industrial production was of diminishing importance.

This essay examines the place of manufacturing in an emerging digital economy. In short, we argue that in order to understand the place of digital innovations in the production process, we require a new nomenclature, one stripped of the grime of the 19th century manufacturing. We will use the word "production," almost a synonym for manufacturing, meaning the creation and making of a good. The real issues in a digital era with powerful 'tools for thought' and diffused "intelligence processing" then are quite basic. *First, what creates value?* The tools for thought permit not only new products, but also a segmentation of the market into different needs and an adaptation of products to the varied segments. *Second, what permits control?* Certainly, the formal character of digital information knowledge permitting control of the production and evolution of the product or service would be increasingly held as formal intellectual property rather than individual or organizationally specific know-how.

However, informal and implicit know-how does not lose its significance in this digital age. Much of the digital world is also protected by the implicit knowledge embedded in the complex system that most software programs present. In an electro-mechanical era, much of the knowledge of product functionality and its development is embedded as organizational "know-how," or as groups of people who know how to do tasks that individuals could not do on their own. While entire production systems include both the formal knowledge of a product design, component specification, or tooling characteristics, the subtle know-how of how they are combined is found in teams of people and larger organizations. That is equally true with complex systems projects and code systems. In one sense they are protected by the privacy of the "formula", or in computers, the privacy of source code. But if the formula or the source code were stolen, how much of the process is rooted in a particular organization's know-how, and consequently not replicable? But before we turn to the implications of this digital event, let us develop the issues in turn, consider the nature of the digital era, and examine the questions of value.

Initially, it is vital to understand the dysfunction inherent in the manufacturing/services distinction. That manufacturing continued to matter with the rise of a service industry was obscured because we were committed to counting, and hence observing, the wrong things. The core notion that manufacturing mattered turned on the observation that the categories of manufacturing and services into which we placed production and employment were hopelessly intertangeled. Large chunks of the service economy were tightly linked geographically to the manufacturing – and indeed agricultural – economy. Lose production of grain, and the Cornhusker Spraying Service dies as well; lose the production of cars and Ace Window Washers comes to a halt. Additionally, firms could not easily control markets in which they were not masters of the production process. As US firms learned in consumer electronics, outsourcing production limited the companies' ability to sustain innovation in product design. Firms lost sight of the importance of manufacturing, and manufacturing innovation, as a strategic tool; that is, as a means to enter a market and move up into the core of the sector. Finally, proponents of the "manufacturing matters" position argued that production was not vanishing but being reorganized. American difficulties competing in manufacturing arose as competitive production strategies emerged elsewhere that forced the reorchestration of production. The character of that reorganization is itself in dispute. One set of analysts talked of post-fordism, lean production, and flexible specialization.

The digital era brings new issues to the process of manufacturing/production reorganization. The story begins and is best understood with the transformation of the consumer electronics industry. After losing position in global markets to Japanese competition in particular, the American industrial comeback was first evident in the new consumer electronics. The competitive advantages were based on a new model of competition which Borrus and Zysman labeled "Wintelism". Competition in the "Wintelist" era is a struggle over setting and evolving de facto product-market standards, with market power lodged anywhere in the value-chain, including product architectures, components, and software. Each point in the value-chain can involve significant competition among independent producers of the constituent elements of the system for the control over the evolution of technology and final markets. In this new era, products like the Intel Processor or the Microsoft Operating System were accessible and open but owned, so that the components, the constituent elements of the system, were open enough that the elements, or new applications, could be interconnected. However, the standards, the Intellectual Property dictated how the constituent elements worked was owned. In the resulting competitive system, the makers of the critical constituent elements rather than the assemblers such as Dell or Compaq dictated the pace of production innovation and market evolution.

At the same time that competition was restructured, production was reorganized into Cross National Production Networks (CNPNs). CNPN is a label we apply to the consequent disintegration of the industry's value-chain into constituent functions that can be contracted-out to independent producers wherever those companies are located in the global economy. CNPNs compromise a clever division of labor in which different value-chain functions are carried on across national boundaries by different firms under the coordination either of a lead MNC for its own production or of a Production Service Company (PSC) who manages the production value chain for clients. This strategic and organizational innovation, at an extreme, can convert production of even complex products into a commodity that can be purchased in the market.

Fordism was an argument about balancing within a national economy rigid production systems and fluctuating demand. Lean production was about production innovation and the relationship amongst national production systems. Flexible specialization was about community. Wintelism in the end is about the integration of production systems across borders.

Where does that leave us in the digital era? Unpacking the influence of the digital revolution on production is no simple task. The digital tool set, the "tools for thought", on which the dreams of economic transformation and business revolution rested, is the critical starting point. Information technologies, data communication and data processing technologies are tools to manipulate, organize, transmit, and store information in digital form. These tools for thought amplify our ability to use and apply information, they amplify brainpower in the way the technologies of the Industrial Revolution amplified muscle power. Let us note two features of this tool set. First, the tools rest on the ability to represent information in digital form, mostly in languages that are built from a mathematics of 0s and 1s that themselves rest on binary representation, and that permits electronic manipulation in the states of "on" or "off". The information age rests on the common digital expression of information. Second, this set of information tools is increasingly integrated and networked. As a result, webs of information are created, transferred, manipulated, turned into products, shared and sold.

The emerging digital tool set and networks mean that information in a digital form becomes critical to firm strategies to capture value and market position. As the discussion is refocused around the role of information (defined as a data set from which conclusions can be drawn or control exercised) the word manufacturing may be abandoned for the more useful term production.

In the digital age, information about the market or as a means of controlling and giving functionality to a product was at the core of the creation of value. Information tools create the product value by identifying how to segment the market, by generating functionality, and by creating the product customization through digital versioning.

If information plays such a critical role in value creation, how can control be maintained in the production process? As noted, many, no doubt, look to Intellectual Property rules and other legal instruments as means to defend formal expressible knowledge. Similarly, formulas that defy reverse engineering may be employed. But informal and implicit know-how does not lose its significance in this digital age.

Let us approach this problem of production in a digital era from a different angle. Does the process of creating value and governing the production process change in the digital era? Consider first that the archetype of the industrial era is the division of labor in Adam Smith's pin factory. The capitalist sets the process and the division of labor, assigning tasks that subdivides the process. The archetype of the digital era may be open source software, a system of distribution innovation where tasks are self-assigned and where even the management of the innovation is voluntary. A political story of the digital age is one of how this process seemingly doomed to chaos is managed with such brilliant success that Microsoft considers itself threatened.

As digital advances permit the reorganization of the division of labor, we should next explore the extension and reconfiguration of the value chain. For instance, the line between the development part of R&D and traditional production erodes when new products continuously require dynamic adaptation of production processes. Production blurs into development.

Our discussion terms the service/manufacturing divide with a new broader label. The term production, as the act or processes of producing something, can encompass a range of products and platforms that provide services. It need not evoke the more limited sense of physical manipulation implicit in the term manufacturing and to step beyond the current data categories that blind us to reorganization.

These issues do not generate uniform implications for all companies, as the answers lie in the character of the particular sectors, and more specifically in the role that digital information plays in those sectors. Hence the place of manufacturing, the organized act of producing a good or service for sale, will vary from a digitized market and product, which finance increasingly is, to sectors like transportation where digital tools are employed to produce a physical product.

The critical question is whether, or when and under what circumstances, production is a strategic weapon and when a commodity. For example, mastery of production is most important in new products and production processes because there is no commodity knowledge. Dell turned the commodity character of PC production into a strategic weapon liking production to the market. The implication, it would seem, is that it is safe to outsource, and to allow learning to take place in limited ways in companies servicing the final product-company, during ordinary times. But not so fast. Who knows when ordinary times are about to stop. And who knows when radical change may make it important to bring production learning in-house. The digital revolution has altered value creation and control. It does so differently for sectors that have a.)Digital Functionality and a Digital Market, b.) New Processes and New Materials and c.) Conventional Products with Digital Functionality and a Physical Function. The task ahead is to understand the flavor of these dynamic processes. The corporate challenge will be to understand where the new development represents competitive threat. The national challenge is to understand clearly that the process of globalization is powerfully shaped by the resources created at the national level.

Production in the Digital Era
Commodity or Strategic Weapon?

Attention to the emerging reality of digital economy reframes the argument that burned 15 years ago as to whether manufacturing mattered, either to firm strategy or national economic well being.[1] For one set of analysts the question was what follows the industrial economy. Over the past several decades a series of labels have proposed central features of the next epoch: the knowledge economy, the information society, and the service economy. One thing these, and other, notions have in common is the conviction that the material production that defined the industrial era will give way to something else, though there is debate as to what that something else will be. By implication each suggests that manufacturing will have a diminished role today and in what comes next.[1]

The conventional argument was that just as an agricultural economy gave way to a manufacturing economy, an industrial economy was giving way to a service economy. Hence, the logic continued that industrial production was of diminishing importance. The argument is that a decline in manufacturing production and a rise in services reflects an inevitable, irresistible historical process.

We ask, then, what is the place of manufacturing in an emerging digital economy? Note as we proceed that we will wobble in the use of the words “production” and “manufacturing.” That is intentional, and anticipates part of our conclusion. Manufacturing has come to imply the old economy, the manufacture of physical goods in factories. The word manufacturing implies smoke and factories. We require a new word; one stripped of the grime of 19th century manufacturing. We will use the word production, almost a synonym for manufacturing meaning the creation and making of a good.

Part I. Manufacturing Matters: The Original Argument[2]

That manufacturing mattered, Stephen Cohen and I argued, was being obscured because we were counting and hence observing, the wrong things. The core notion that manufacturing mattered turned on the observation that the categories of manufacturing and services into which we placed production and employment were hopelessly intertwined. Two examples reveal the problem. A window washer employed by General Motors is a manufacturing employee. If that function is outsourced to Ace Window Washer, that worker becomes a service employee. If a farmer in Nebraska sprays his own fields he is a farm worker; if he hires Cornhusker Spraying, then the sprayer is a service employee. The present way of categorizing employment obscures the character and significance of industrial reorganization.

Similarly, firm level data have for years hidden the influence of technology. Does technology create or destroy jobs? At the firm level, often the data suggests that adoption of innovative technologies destroy jobs. At the plant level we discover that those plants that are technologically modernizing add jobs; those that do not keep pace tend to lose jobs. Why? The modernizing plants evidently capture market share; technological innovation and internal reorganization is not a competitive option.

In order to understand the intertwined reorganizations several distinctions in the service categories need to be made. We must separate personal and social services from business services. The business services are the ones entangled with manufacturing. Hence, to understand the reorganization of production, we want to divide out all the government's social services from welfare to driver's licenses and all the personal services from haircutters to nannies. Additionally, we want to separate out those service activities that are downstream from production, such as selling and advertising a product. We need to focus on upstream activities, those things that go into making the product in the first place. If phone services are contracted out, here they are part of the production process, as would be our window washer, and an outsourced machine repairperson. Those upstream service workers who are part of the production process must be included in our assessment of the employment or value-add of manufacturing. If the manufacturing activity vanishes, then those jobs and that value vanish as well.

The core of the manufacturing matters position is developed from three starting points. One part was that large chunks of the service economy were tightly linked geographically to the manufacturing -- and indeed, agricultural -- economy. Lose production of grain, and the Cornhusker Spraying Service dies as well; lose the production of cars and Ace Window Washers slows to a halt. In many cases the line separating service employment from production employment was simply one of the organization of the company. Outsourcing often transformed manufacturing jobs into service jobs; the market and the firm structure changed, but the jobs remained. Consider as manufacturing employment those service jobs tightly linked to manufacturing activities, then some estimates run in the late 1980s run as high as 50% of employment.[3] Hence the service employment/production numbers were the *beginning* of a more complex story, not its defining feature.

The second part was an argument that firms could not easily control markets in which they were not masters of the production process. In consumer electronic products from TVs through VCRs and in automobiles as well, production innovation in Japan clearly permitted Japanese companies to capture market share in global markets. As important, if a firm began to outsource production, its ability to sustain innovation in the product design was, arguably, limited. It would have less sense of what might be built and would not be able to sustain innovation. Consequently, production mattered.

Firms lost sight of the importance of manufacturing, and manufacturing innovation, as a strategic tool. Mass production, of course, transformed and indeed created a consumer durables industry. But by the mid-1960s the established conventional approaches to production, and the market, were vulnerable. While the VW Beetle established a market niche for small fuel-efficient cars that Detroit thought it could ignore, the Japanese took beachheads at the low end of the market. From those beachheads, using manufacturing as a strategic weapon, they moved up into the core of the auto sector. Indeed the Japanese position in consumer durable manufacturing was built on manufacturing innovation, and in the end suggested the notion that you can't control what you can't produce. We will return to the nature of that lean production strategy in a moment. For now, let us note that Japanese entry into the sequence of consumer durable markets was marked by four elements. 1) The entry into each market -- radios, TVs, autos -- was consistent; enter the lower end undefended or less defended segments. That initial footprint provided a base to develop expertise in production and product that permitted a wider market position. 2) Production innovation underpinned the expansion of market position. The production innovation allowed distinctive product and market strategies. It took quite sometime for Western producers to accept that Japanese were really low cost producers, that the cost advantage did not hinge on cheap labor but rather on production organization, and that quality in the proper organization could come for free. 3) Product innovation soon rested on distinctive production organization. It was not just distinct packages of quality and cost that were possible, but rather the ability to generate distinctive product such as the Walkman that hinged on design, component and assembly innovation. That production innovation came soon to be embedded not just in the organization of the factory floor, or the supply chains with just in time delivery reducing inventory. Rather they came to be expressed in the tools of the trade, from machine tools in metal cutting/bending industries through semi-conductor equipment in higher tech segments. 4) American companies and policy makers facilitated Japanese strategies. The companies did so by retreating from defense of the simpler segments of the product lines. Policy makers were adopting quantitative restrictions on our markets that made it attractive for the Japanese producers to aggressively pursue the market segments that American companies thought were impregnable. Simply, faced with surges of Japanese imports and caught with a policy of free trade and open markets, American policy makers either imposed temporary quantitative restrictions to limit imports or asked the Japanese to self-limit. That was an invitation to enter the higher value added market segments. For the Japanese, then, with demand exceeding permitted supply, producers would clearly choose to sell the more valuable products to maximize revenue.

The third part of the alternate position was that production was not vanishing but being reorganized. The service employment numbers, and the ambiguity of their meaning, a matter suggested above and to which we return in a moment, hide the fundamental reality of reorganization but not of the elimination of manufacturing. American difficulty competing in manufacturing was because more competitive production strategies had emerged elsewhere that forced re - orchestration of production. The character of that reorganization is itself in dispute. One set of analysts talked of post-Fordism, flexibility specialization, and lean production. Their focus on the reorganization of production opened issues of firm strategy, labor strategies, public policy, and political dynamics. [4] These analyses were for the most stories about the evolution of the past, about the reorganization of an electro-mechanical epoch, and not about the implications of what was to come.

For others, ourselves included, the starting point in understanding the manufacturing reorganization begins with the recognition that the digital era brings new issues. And that recognition comes first with the transformation of the consumer electronics industry. By the early 1990s the Japanese competitive surge that had triggered the interest in manufacturing had receded. Part of the reason of course was the collapse of the Japanese bubble, which constrained both domestic markets and company financing. Part involved an American industrial comeback. It is that American comeback, not the Japanese collapse that concerns us here. That comeback involved, certainly, learning about approaches to what has been labeled lean production. That set of production innovations could only, in our view, have been generated during Japan's developmental decades as domestic demand and production exploded generating intense but controlled internal competition that could be balanced, when rapidly expanding supply swamped domestic markets, by exports. [5] In an important sense the Japanese production represented a culmination of production innovation in the electro-mechanical and metal bending industries.

The American comeback was, likewise, generated at one possible historical moment; amidst weakened confidence in domestic production capacity, an entirely new model of competition emerged. Borrus and Zysman labeled it "Wintelism". That competition production model was first evident in the New Consumer electronics. Whatever the label it represented the first stage of production and competition in a digital era.

For our story, the most significant development was a tripartite evolution in product and production. A new consumer electronics segment emerged, represented most clearly by the PC, based on digital processing and communications network connectivity. The miniaturization and production skills in the smaller TVs, the electro-mechanical know-how embedded in the VCR, Walkman and Sony CamCorder were suddenly less critical. The core value-added in the PC, for example, resided in critical components such as the Intel microprocessor and the Microsoft Operating system. The production process shifted from electro-mechanical expertise to chip management - how to connect the electronic components, put them on boards, and manage the intelligence they permitted. The electronic products themselves had traditionally been grouped into two sets; those with open standards such as televisions in which production skills differentiated producers and those with close standards such as IBM computing systems in which the electronic operations of the whole system were owned proprietary knowledge. In this new era products were accessible and open but owned, so that you could understand at least part of the Intel processor or Microsoft operating system. The components, the constituent elements of the system, were at least open enough that the elements, or new applications, could be interconnected. But the standards, the Intellectual Property dictating how the constituent elements worked was owned. The providers of the final system were often pushed into the role of assemblers. The resulting new era, the makers of the critical constituent elements rather than the assemblers such as Dell or Compaq dictated the pace of product innovation and market evolution. Hence, we labeled the era as Wintelist, suggesting the distinct power of Windows and Intel processors to shape markets. Consequently, the assemblers instead of capturing distinct value added with distinctive IP were forced into low-margin highly competitive segments. IBM had always provided a package of service and support for its systems, so that it could escape the low margins, but often not its increasing dependence on components of some merchant companies. Eventually IBM would seek to escape dependence on the Microsoft/Intel duo by turning to the Open Source movement best known for its Linux systems and Apache servers as an alternate approach to proprietary software development, and production.

A. Manufacturing in the Digital Era

Where does that leave us in the digital era? Most importantly, production in a digital era is not another chapter in the industry-to-services sequence and debate. If anything the distinction is less useful than ever. Consider accounting which has been provided as a personal service; put the principles and processes on a disk and it becomes a product; put the principles and processes on a server, sell it as an ASP (application service provider) and it becomes a service again. Take a product such as pharmaceuticals. Design them to person specific characteristics determined by genetic profiling, and you have a service company. Product or service: a truly pointless debate that hides the basic issues.

What are those basic issues? The real issues in a digital era with powerful tools for thought and diffused "intelligence processing" are quite basic.

- What creates value?
  The tools for thought permit not only new products, such as high quality audio and video or financial services, but also a segmentation of the market into different needs and an adaptation of product to the varied segments. Data mining of the information sets that abound permits differentiation of customer. Microprocessor control of cars to printers permits adaptation of often-common product to those segments. What differentiates a fast printer from a slower one? The price customers will pay and the instructions in the processor that controls the speed of the printer.

- What permits control?
  Knowledge that permits control of the production and evolution of product or service increasingly is held as formal intellectual property rather than individual or organizationally specific know-how. What makes a BMW 5series a distinct product that commands prices far above those of a Ford Taurus is a matter of know-how and branding. Intellectual Property Rights permits Microsoft to capture value from an operating system. Copyright and patent become ever more important. And critically, the rules of IP are set heavily in response to the requirements and needs of the media industry.

These are not general implications for all companies, as the answers lie in the character of the particular sectors, and more specifically in the role that digital information plays in those sectors. Hence the place of manufacturing, the organized act of producing a good or service for sale, will vary from a digitized market and product[6], which finance increasingly is, and automobile or transportation where the good--or service-- remains inherently physical. But before we turn to the implications, let us develop the issues in turn, consider the nature of the digital era, and examine the questions of value.

Part II. From Fordism to Wintelism

Here in Part II we begin to locate our digital story, of which Wintelism is the first phase, as one of a series of approaches to markets and production. Each story of production and competition emerges from a particular moment and a specific place in industrial history as part of a sequence of developments[7]. This section highlights three stories:

- *mass manufacturing*, or Fordism, that emerged in the United States in the latter part of the 19th century, and later consolidated itself in the automobile industry, to become the model of industrial development in the years after WW II
- *lean production,* and "developmentalism", that emerged in Japan in the1970s
- *"flexible specialization"* and community-based growth that was first highlighted in particular Italian and German industrial regions.

Each of these three stories is also a synthesis and a method--a more general and influential interpretation of advanced countries.[8] Hence, we could present this material twice: once as the narrower market tale of a sequence of competitive developments, and once as a method and metaphor.

A. Fordism and Mass Manufacture

Mass production is broadly understood to mean the high-volume of standard products made with the complete and consistent interchangeability of parts that could simply be connected using machines dedicated to particular tasks that are manned by semi-skilled labor.[9] (Indeed, the definition is now so conventional that arguments contrasting industrial developments to mass manufacture do not always provide a definition.) A range of features is hung on to that basic definition. The features include:

- the separation of conception and execution—managers design systems that workers, slotted into rigidly defined roles to match them to machine function, operate;
- the "push" of product through these systems and onto the market;

- large-scale integrated corporations, whose size and dominance reflected mass production's economies of scale, dominated the markets.

The operation of this system became embedded in the institutional organization of the economy, the rules that shaped market interactions and transactions. Hence "Fordism", as distinct from mass manufacture, becomes a social and political system built upon, or better still created to implement, an approach to industrial production and markets in an era dominated by mechanical engineering and metal bending industries. Within the Fordist story, market control is exercised held by large companies.

The sources of both mass manufacture, and its particular manifestation as Fordism, have their roots in the trajectory of American industrial development. The story emphasizes the innovation of interchangeable parts leading to the assembly line, the homogeneous but prosperous and growing market that created demand for standard product, and the abundance of semi-skilled labor suited to the assembly line system of mass production. The political battles generated both a particular set of market rules that permitted, even encouraged, vertical integration and labor market organization that implemented management control of the shop floor.)[10] Importantly, mass production created, and is rooted in, the consumer durable markets for mechanical (automobile) and electro-mechanical (refrigerators and the like) products, while the technology of interchangeable parts grows out of the metal cutting mechanical engineering sectors. There is, arguably, more than one national form of mass production or Fordism, but the prototype certainly was the American case.

The particular mass production approach to manufacture and markets entrenched a particular set of technologies, if one sees social context shaping technology. Alternately, if one sees the unfolding of technological possibilities driving market arrangements, the particular possibilities of emerging technology generated the specific approach that we call mass production. In either case, for most analysts advanced industrial society seemed characterized by large, integrated firms seeking to impose on markets products produced on high-volume, dedicated lines manned by semi-skilled workers. Scale implied rigidity, and the economic management counterpart of that corporate rigidity became the policy question of how to avoid business cycles. Booms and busts implied worker dislocations, and the social/political management counterpart of business cycle management became how to use a welfare state to cushion not only the economic dislocations but also the political dislocations. Fordism thus implied an analytic method. The analytic method was to ask what institutions and policy sustained a dominant system of production, and how a balance is maintained between the micro-economic logic of production and stability in the macro-economy.

Fordism thus became mass production with Keynesian demand management, full employment, and a welfare state. It was both a characterization of an era and a goal to be pursued. With its emphasis on mass markets and arrangements of labor, welfare, and national demand management, attention was focused on *national* capitalisms. The significance of local or regional institutions faded. How widely the Fordist system actually diffused is both unclear and critical to later argumentation. There were two diffusions; one is the system of mass production and the other is the particular set of policies associated with Fordism. The answers are different for each. For example, when the Japanese auto industry was reconstructed in the 1960s it evolved into a lean system of flexible volume production. Japanese growth in the same period hinged on rapid internal development and export markets, not on demand management. If Fordism was never fully implemented, then post-Fordism is a misstatement; there are alternate lines of industrial development, not a clear sequence.

In any case, Fordist mass production was associated both with American industrial development, military success, and post-war hegemony. Beginning in the 1960s two alternate configurations—flexible volume production and flexible specialization—emerged, or at least caught our attention. Both claim to provide static flexibility, the capacity to vary product mix within a particular generation of production, and dynamic flexibility, the ability to move between product generations and steadily advance the productivity of the production system itself.[11] While each is rooted in the industrial development of a particular place, each has served as an alternate *general* model of firm competition and national policy.

B. Flexible Mass Production, Lean Production, and Developmentalism

Japan's automobile and electronics firms burst onto world markets in the 1970s and consolidated powerful positions in the 1980s. Their success has its foundations in the interconnected production innovations loosely called flexible production, or lean production, or flexible volume production.[12]

Characterizations of the Japanese production system emphasize that it provides flexibility of output in existing lines as well as rapid introduction of new products, which permits rapid market response. High quality measured in defects has come hand in hand with lower cost. The elements are in fact bound together.[13] Pulling a product through the system links the factory more closely to the market while reducing the need for buffer stocks. Reducing buffer stocks, which certainly reduces stockage costs, makes just-in-time delivery of components a necessity, and the management of supply flow a critical matter. Transferring considerable responsibility to the production line also creates mechanisms for detecting and correcting defects within the system that can then be interpreted by formal methods of statistical process analysis. The use of production centers with a variety of lighter-weight tools permitted flexibility in product mix, while at the same time adjusting the line management to the necessities of numerically controlled (NC) machine tools.[14] The core Japanese assembly companies of the lean variety have been less vertically integrated than their American counterparts, but they have been at the center of vertical Keiretsu that have tightly linked the supplier companies to their clients.

A distinctive approach to volume manufacturing, however labeled and characterized, emerged in Japan during the years of fast growth and was firmly in place by the time of the first oil shock in the early 1970s. In our view the distinctive features of the Japanese production system were a logical outcome of the dynamics of Japanese domestic competition in the rapid growth years.[15] A sketch of the argument begins with the intense competition among Japanese firms in the domestic market behind protected barriers using imported technology and materials. With rapidly expanding markets, no foreign rivals, easily available finance for critical companies in favored sectors, and a competition among firms implementing borrowed technology, companies needed to ride the production curve and learning economies to success. The logical consequence was that it was strategically necessary to maximize market share.[16] This in turn had it's own consequences. First, the large and now well-known core assemblers such as Toyota or Matsushita were at the beginning members of groups of companies, labeled after WWII as Keiretsu, and short of capital. Contracting with related supplier companies shared the capital demands and market risks; the assemblers thus generated tiers of supply relationships and the necessity of joint component development. The introduction of the Kanban system of "pull through" thus implied and could induce just-in-time delivery. Just-in-time delivery required limited defects.[17] Small firms thus had a significant role in the story, but within a sphere dictated by the large core companies and not generally as independent players. Japan was characterized by vertical, tiered production relationships dominated by the largest companies. The large assemblers, thus, maintained both controls over the supply chain and the link to the market. Second, while borrowing technology and continuously expanding production in growing markets, firms had to organize internally to effectively capture the learning curve possibilities. Firms that were more effective at responding to markets and organizing internally to capture learning curve gains had a distinct competitive advantage. Some accounts emphasize the strategic insights at Toyota where the lean production system first was implemented fully. Other stories emphasize the difference in shop floor organization and union structures between company unions at, for example, Toyota and Nissan.[18] In any case, effective development of flexible volume production required distinctive strategies from the market to shop floor organization to supply chain management. National government programs such as those that subsidized numerically machine tool development mattered in this series of production innovations, but the significant government interventions were less sector specific actions influencing particular companies than the creation of the competitive market logic than induced goals of market share and exports.

Protected domestic markets and exports were decisive, in our view, and generally understated in the accounts of the emergence of the distinctive system of lean flexible volume production. These elements are emphasized in stories about trade politics, but not those about industrial and technological innovation. While company rivalries behind protected markets induced many of the strategies that produced flexible volume production, exports helped permit the transformation from "fragile" to "lean" production. Domestic demand, savings, and investment are the key to the story of the Japanese high growth years. But exports are not simply the product of that internal success, but rather were key to production innovations that facilitated international market positions.

The argument is simple.[19] The relationships of production and development in these productions systems are, at best, delicate. Just-in-time delivery, subcontractor cost/quality responsibility, and joint component development push on to the subcontractor considerable risk in the case of demand fluctuations. True, there were techniques to continuously reappraise demand levels and indicate to 'client' firms their allocations so that the client firms could in turn plan. This reduced unpredictability throughout the system. But if demand moved up and down abruptly, those techniques would not have mattered. True, government and corporate programs to reduce the capacity break-even point in small firms helped. Nonetheless imagine that Japan's emerging auto sector had to absorb continuously the stops and starts of the business cycle that typified Britain in the 1950 and 1960s. Would the trust relationships that are said to characterize Japan have held up? Could the fabric of small firms have survived to support just-in-time delivery and contractor innovation? Simply a smooth and steady expansion of demand typified the Japanese market in sectors such as autos and facilitated these arrangements and developments.[20] The high growth rates--combined with the need to re-equip Japan in the post war years--created the basis of the continuous expansion. But domestic growth did fluctuate and the rivalries for market share led consistently to over-investment, or excess capacity, in the Japanese market. The story about Japan told by Yammamura and Murakami, Tsuru, Zysman, and Tyson, and by Tate in the case of the auto industry shows that the excess capacity was "dumped" off onto export markets. Seen differently, these exports permitted a steady and smooth expansion without which the production innovations outlined here would not have emerged. The developmental strategies of Japan were essential to its production innovation.

Thus while the Fordist story highlights national strategies for demand management, this story of lean production and developmentalism highlights the interaction among advanced countries in international competition. The Fordist method looks at the problem of offsetting rigidities in national capitalism--managing the business cycle and its social and political consequences. The Japanese case of lean production obliges us to consider the comparative development of capitalism, the interaction of national systems in international markets, and the distinctive "logics" of market competition that are therefore created.

The mechanisms and sources of the Japanese flexible volume manufacturing system attracted intense attention because of the stunning world market success of the Japanese companies in consumer durable industries requiring complex assembly of a large number of component parts. The innovators were the core auto and electronics firms who in a hierarchical manner dominated tiers of suppliers and sub-system assemblers; the production innovation was the orchestration and re-organization of the assembly and component development process. But flexible volume production was not the only significant innovation.

C. Flexible Specialization

This story should be told twice. The first time, one would tell it in order to examine its analysis of particular industrial innovations in Italy and Germany. The second time one would tell the story to explore the more general claims that are broader and bolder, but more suspect. That general theoretical argument we place here in an appendix, for those who are interested. Let us focus on the core story, the first story.

The "Third Italy" and the Germany of Baden-Wurttemberg were the first prominently displayed examples of an approach in which craft production, or at least the principles of craft production, survived and prospered in the late twentieth century. The particular political economy of the two countries is shown to have given rise to distinctive patterns of company and community strategies.[21] Indeed, these two cases gave rise to the notion of flexible specialization. "Craft production or flexible specialization", argue Hirst and Zeitlin, "can be defined as the manufacture of a wide and changing array of customized products using flexible, general purpose machinery and skilled, adaptable workers."[22] Communities consisting of groups of small companies, organized in what are perceived as Twentieth century versions of industrial districts are argued to be able, in at least some markets and some circumstances, to adapt, invest, and prosper in the radical uncertainties and discontinuities of global market competition more effectively than larger, more rigidly organized companies. Their technological dynamism distinguishes them from the small firms that emerged during the Great Depression of the 1930s. "These districts escape ruinous price competition with low-wage mass producers," Sabel argues, "by using flexible machinery and skilled workers to make semi-custom goods that command an affordable premium in the market."[23]

The emphases in these discussions are the *horizontal connections,* the connections within the community or region of peers. Indeed some versions of the flexible specialization story emphasize the capacity of firms that are one day the prime contractor, arranging matters with their business neighbors, to shuffle their roles and serve as subcontractor the next. This community of peers is certainly distinct from the *vertical or hierarchical connections* of the dominant Japanese companies. Links to the market and to the institutional infrastructure of business are maintained by the community of peer firms. In some presentations, these communities arose earlier and alongside mass production but were not noticed because the analytic and public focus was elsewhere, or were not significant because the distinctive capacities of these communities of companies were not decisive, or more broadly significant, until later. In other arguments, flexible specialization emerges out of the logic of the limits of mass production itself. Italy, in this line of argument, develops dualism within the advanced Northern Regions and companies.

The dualism comes from the rigidity of large firms that have not only fixed capital costs, but also fixed labor costs and the associated costs of large-scale labor conflict. Preserving a core production within the parent company that is going to be needed even with radical expansions and contractions of the economy, smaller lot production is contracted out so that the companies would not be rigidly locked to the additional or marginal production.[24] The small lot producers were initially assumed to be higher cost manufacturers that provided in their flexibility, albeit at a higher price, a desperately needed antidote to rigidity. In fact, many of these small producers broke loose from their origins, becoming efficient producers along new principles and attacking markets they did not initially imagine. These companies emerged within and in response to the system of mass production. The creation of these modern craft producers and the social infrastructure on which they depend was a political outcome emerging amidst intense social conflict.[25] Of course the two stories, the early existence of efficient craft-styled production and the emergence of a new generation of craft companies, can be accurate.

The contribution of this original and narrow version of the flexible specialization story is substantial and several. First, a significant innovation in production and competition emerging in Italy and Germany was identified. Second, the character of the political and social process generating that production system was delineated. Third, more generally, Sabel's *Work and Politics*[26] argued persuasively that production systems were not inherently rooted in a technological structure, but rather a production system and institutions of a political economy in general were created by conflict and rivalry. Fourth, the community, or the sub-national region, in addition to the nation, is a significant actor in the stories of industrial development. In stronger versions of this argument, the case is made or implied that the emergence of "flexible specialization" has underpinned the growing *political* significance of the regions, while in other presentations communities politically suited to provide the infrastructure that "flexible specialization" requires breed this new brand of competitive strategy.

The evident question to pose to the arguments of the original, but narrower, version of the argument is how significant are these developments?
We might define significance in terms of:

- *The percentage of production involved in flexible specialization.* As we shall see in a moment this requires defining what is a firm or community of firms involved in flexible specialization. Whether smaller craft-styled firms have become a larger or more significant feature of the economy has been taken as one element of that debate. One question is whether pools of small start-ups, such as those in Silicon Valley, that with each generation of technological development produce new giants and in which the small start ups themselves are often spin-offs of giant firms, should be considered examples of flexibly specialized peer companies, or simply part of a different and equally interesting industrial dynamic.
- *Whether flexible specialization defines core terms of competition in a particular sector or is simply periphera*l. For example General Motors and Toyota define the core features of the auto industry, not their second tier suppliers.

The original basic story identifies one of several roads to industrial development and responses to competitive markets in the last part of the twentieth century. This initial story which highlights the role in the new industrial competition of craft firms, that emphasizes that the forms of the market and political economy are political created and not simple unfolding of an interior technological logic, and which highlights regional/local institutions and community learning is to us a significant and substantial contribution. *The original "flexible specialization" story* thus defines one route to adaptation and adjustment in the world economy.

But the argument in some hands is pushed beyond these boundaries, both as an empirical claim and an analytic method. The broader enterprise of demonstrating roads untrammeled in the past and possibilities unexplored in the present is fascinating and intriguing. The heuristic tools suggest analogies to experiences elsewhere and certainly provide policy guidance to communities and regions seeking to advance their competitive position. The contributions of these efforts are substantial. But when the broader enterprise takes the ideal type as a possible future and uses clues and hints as hard evidence of that unfolding future, the "flexible specialization" enterprise becomes a set of blinders. (The long note here elaborates that argument).[27]

There is an analytic method involved in examining each of these national stories and historical phases of industrial development. Let us state it formally. A four-step approach to link institutional and social contexts to the dynamics of national markets and technology systems characterizes this analysis.[28]

Step 1: Each economy consists of an institutional structure. The institutional organization of politics and markets defines the choices of each actor. It induces nation-specific political and economic dynamics.

Step 2: That institutional structure of the economy, combined with its industrial structure in a more classic industrial organization sense, creates a distinct pattern of constraints and incentives. This defines the interests of the actors as well as shaping and channeling their behavior. The interaction of the major players generates a particular "policy logic" and a particular "market logic". Since the national institutional structures are different, there are, as a consequence, many different kinds of market economies.

Step 3: Market logic, specific to a particular national institutional structure, drives corporate choice, thus shaping the particular character of strategy, product development, and production processes in a national system. A specific market logic (and political logic) then induces distinct patterns of corporate strategy (and government policy), and therefore encourages internal features of companies (and the government) that are unique to that country. There are typical strategies, routine approaches to problems, and shared-decision rules that create predictable patterns in the way governments and companies go about their business in a particular political economy. Those institutions, routines, and logics represent specific capacities and weaknesses within each system.

Step 4: Not only trade competition but patterns of technological development must in part be understood as an interaction of these national market logics. Differences in corporate strategy and access to markets and technology create patterns of international trade competition.

This logic suggests why phases of industrial development emerge at particular historical moments in particular places, though the organizational and technological apparatus they generate can be transferred. That leads us then to Wintelism.

Part III. The Beginning of the Digital Era: Manufacturing, Standards, and The American Comeback[29]

The American production comeback began in the new consumer Electronics. What is a consumer electronics product? Anything stocked and sold in a discount store with a guarantee. The "old" consumer electronics consisted of the entertainment products from TVs and radios through VCRs and the Walkman and game players. They involved complex electromechanical goods principally for the passive "reception" of media content. It played to all the strengths created by the Japanese in the auto sector and machine tooling, precision controlled manufacturing. The "New" consumer electronics, as Michael Borrus has argued are networked, digital, and chip based. They involved products from Personal Computers through mobile devices. The nature of manufacturing and the sources of functionality change dramatically. The engineering skills moved to chip based systems given functionality by software.

This first chapter of the digital era can be best characterized by two elements: Wintelism and Cross National Production Networks (CNPNs). Wintelism marks the beginning of the digital era; CNPNs began to mark the new approaches to production that result. In this chapter, outsourcing begins as a tactical response principally aimed at cost savings and evolves into the strategic instrument of supply chain management. The shifting character of competition drives this change; the cross-national production networks facilitate its implementation.

"Wintelism" is the code word Michael Borrus and I use to reflect the shift in competition away from final assembly and vertical control of markets by final assemblers.[30] Competition in the "Wintelist" era, by contrast, is a struggle over setting and evolving de facto product-market standards, with market power lodged anywhere in the value-chain including product architectures, components and software. Each point in the value chain can involve significant competitions among independent producers of the constituent elements of the system (e.g., components, subsystems)—not just among assemblers—for control over the evolution of technology and final markets. CNPN is a label we apply to the consequent dis-integration of the industry's value-chain into constituent functions that can be contracted-out to independent producers wherever those companies are located in the global economy. This strategic and organizational innovation, at an extreme, can convert production of even complex products into a commodity that can be purchased in the market.

A. The Emergence of Wintelism: From Assembly to Standards, Components, Subsystems and Architectures[31]

In the auto industry, competition remains centrally a battle among assemblers such as Toyota, GM, and Renault who design and integrate final products. Its production principles became a model for all competitors in the industry to emulate. A set of production innovations, first those at Ford and then those at Toyota, altered conceptions of best practice in organization, technology, and management. Ford's innovation was the implementation of mass production; Toyota's innovation was a reorganization of mass production to create flexibility with volume. Both innovations created a decisive market advantage.

In the new era, the electronics and information technology industries play a similarly influential role. In electronics over the last decade, by contrast to the auto industry, the terms of competition have shifted away from final assemblers and the strategy of hierarchical (i.e. vertical) control of technologies and manufacturing. “Wintelism” is the code word that best captures the character of the new global electronics era because Intel and Microsoft pioneered many of its dominant industrial and business practices and are now leveraging their control over PCs to alter the terms of competition in other informatics markets.

The pre-Wintel electronics industry was dominated by assemblers, i.e., systems producers who designed, marketed, and assembled, the final product with a structure and strategy similar to the auto industry. Early post-war American producers like GE, RCA and IBM prospered with quite traditional advantages of scale, vertical integration and, for some products, mass production. On a similar model of vertical control, IBM dominated the computer segment of the electronics industry and extended its franchise into Europe and Asia in pursuit of new markets. Similar strategies produced dominant players like Western Electric and Siemens in the telecommunications segment of the market.

The early 1980s dominated essentially all electronics product-markets dominated by large-scale producers such as IBM, Siemens, Matsushita, NEC, and Toshiba. They produced fully proprietary systems whose key product standards—i.e., the technical specifications that describe the system architecture and enable the pieces of the system to inter-operate as a whole and with each other—were either fully “closed” or fully “open.” A fully open standard is one in which the technical information necessary to implement the standard is in the public domain—i.e., fully available on a nondiscriminatory and timely basis to anyone. This was the case with most consumer and many communications interface standards like TV or fax broadcast standards. With the relevant technical information in the public domain, products like TVs and radios built to such open standards became commodities in which scale, quality, and cost, were the defining features of competition in highly contested markets.

By contrast, telecommunications and computer firms built to "closed" standards in which the relevant technical information was owned as intellectual property and NOT made available to anyone other than through legally permissible reverse engineering. IBM's mainframe computers epitomized such proprietary, closed systems. Here, too, vertical control over technologies and manufacturing was essential especially in the early stages of competition when new systems were introduced. In sum, then, *with both closed and open systems, vertical control over technologies and manufacturing was the key to market success—in order to capture closed system rents and lock-in customers to proprietary standards or to compete on implementation, quality and price in markets for the system that implemented open standards.*

This era of proprietary systems built to open or closed standards lasted until the early 1980s. By the mid 1980s, new electronics product-markets began to converge on a cost-effective, common technological foundation of networkable, microprocessor-based systems (of which the PC is emblematic).

A dramatic shift in the character of electronics products—from the prior era's proprietary systems built to fully open or closed standards, to the Wintelist era's 'open-but-owned' systems built to 'restricted' standards. In the new systems, key product standards, especially the interface specifications which permit interoperability with the operating system or system hardware, are owned as intellectual property but made available to others who produce complementary or competing components, systems, or software products. Hence the systems are 'open-but-owned'.[32] The relevant technical standards are licensed rather than published, with either the universe of licensees, the degree of documentation of the technical specifications, or the permissible uses, 'restricted' in some fashion.

The shift to the new system was accelerated by two factors. One was the increasing cost and complexity of continuing innovation, which made it increasingly difficult for any one company, even IBM, to maintain ownership and control over all of the relevant technologies. The other shift was toward increasingly strident demands from major industrial users as they moved their business operations onto information networks, for increasing interoperability of complex systems purchased from multiple vendors.[33]

But the move to such systems was pioneered, as perhaps it only could have been, by IBM with the IBM PC.[34]

In this new epoch, firms located anywhere in the value chain can, potentially, control the evolution of key standards and in that way define the terms of competition not just in their particular segment but, critically, in the final product markets as well. Market power has shifted from the assemblers such as Compaq, Gateway, IBM, or Toshiba, to, among others, key producers of components (e.g., Intel), operating systems (e.g., Microsoft), applications (e.g., SAP, Adobe), interfaces (e.g., Netscape), languages (Sun with Java) and to pure product definition companies like Cisco Systems and 3COM. What all of these firms have in common is that, from quite different vantage points in the informatics value chain, they all own key technical specifications that have been accepted as de-facto product standards in the market. Each beat-out rival standards.

Such Wintelist strategies effectively attenuate the link between market power and the *ownership* of the assets of production that characterized the prior era of competition, and at the extremes as with a firm like Cisco Systems can completely decouple control of final markets from ownership of manufacturing assets. For Wintelist firms, ownership and manipulation of their de facto standards are barriers to entry considerably more effective than the barriers of scale and vertical control over technology and production in the prior era because they are far harder to duplicate. The creative use of intellectual property rights and associated licensing strategies define defensible market position more than manufacturing scale as the basis of competitive advantage. In this era, even competition at the assembler level over system platforms is as much about standards as it is about production: the desire of Sun to widely license its Java language to other assemblers, or of Oracle to define and widely disseminate the architecture for a 'network computer' (NC) tailored for Internet functionality, really represent their efforts to supplant the market dominance of standards and architectures controlled by Microsoft and Intel.

Another element was at work pushing toward the decomposition of the internally owned and managed manufacturing structure was the sheer technological complexity of modern industry. No one, no matter their scale and sophistication, could do all the things that mattered. "The increasing cost and complexity of continuing innovation made it increasingly difficult for any one company, even IBM, to maintain ownership and control over all of the relevant technologies."[35] IBM and the IBM PC led the way into the new order.

> "In order to get to market fast and exploit a market window opened by Apple (who had adopted a quite traditional proprietary systems strategy), IBM pieced together the first open-but-owned PC using its own proprietary BIOS (basic input-output system), and a variety of components and software from numerous third-party vendors. It invited cloning to establish the market. Once firmly entrenched, IBM intended to bring the product back in-house and make it increasingly proprietary. It presumed that a traditional strategy of unsurpassed scale and vertical control of technology and manufacturing would fend off the clones. It was wrong. Unfortunately for the computer giant, it permitted key standards in its PC to be owned by others (especially Intel for the microprocessor architecture, and Microsoft for the operating system) who innovated at the furious pace that focus and specialization permitted. Gradually, they took control of the evolution of the PC's key standards. In concert with the clone-makers, Intel and Microsoft wrested control of the PC itself from IBM. Strategies to set and control the evolution of de facto standards were developed. Business speed (e.g., rapid product cycles, fast time to market) was rewarded. Wintelism was born."[36]

Increasing technological complexity driving outsourcing was not, importantly, restricted to the electronics industry. Perhaps nowhere else did control of a particular constituent element of the product provide such significant market control. But the array of skills required in modern manufacturing could not all be developed in house.

In this Wintelist era, manufacturing and production do not vanish in significance; rather they shift location in the story. It remains true that you cannot control what you cannot produce.[37] But the ways of implementing and controlling production have changed. As we argue next, Wintelism has an organizational counterpart, a distinctive system of production that we call the international production network, or Cross-national Production Network.

B. The Counterpart to "Wintelism": Cross-national Production Networks and The Manufacturing Services to Construct Them

Fordism, we saw, was an argument about balancing within a national economy rigid production systems and fluctuating demand. Lean production was about production innovation and the relationship amongst national production systems. Flexible specialization was about community. Wintelism in the end is about the integration of production systems across borders.

We are arguing that the strategic importance and hence the organization of production has changed as competition and value-added have moved away from assembly. The defining competition has been the rapid evolution of the constituent elements of the system being assembled and to the creation and evolution of de facto market standards in all of those areas. Cross-national production networks (CNPNs) and contract production services are the organizational counterparts of that shift. CNPNs comprise a clever division of labor in which different value-chain functions are carried on across national boundaries by different firms under the coordination either of a lead MNC for its own production or of a Production Service Company (PSC) who manages the production value chain for clients. As important, CNPNs express the reduced need for companies to control production through ownership or direct management of each piece of the value-chain. To be more specific, by a firm's cross-national production network we mean:

> The organization, across national borders, of the relationships (intra and increasingly inter-firm) through which the firm conducts research and development, product definition and design, procurement, manufacturing, distribution, and support services. As a first approximation, such networks comprise a lead firm, its subsidiaries and affiliates, its subcontractors and suppliers, its distribution channels and sources of value-added product or service features, its joint ventures, R&D alliances and other cooperative arrangements

> (like standards consortia). In contrast to traditional forms of corporate organization, such networks boost a proliferation of non-equity, non-arms-length, cross-border, inter-firm relationships in which significant value is added outside the lead firm and entire business functions may be outsourced. [38]

More is at issue than simply lower labor costs that permit particular components to be built or assembly processes to be conducted at offshore production locations. Rather, intra-sectoral trade and investment link together diverse production functions across national borders to create complementary production arrangements which individual producers and nations would be incapable of maintaining independently. A firm might use specialist producers of computer displays in Japan, printed circuit boards assembled in China, disk drives from Malaysia, digital design and final assembly services in Taiwan, software from Bangalore, and process development in Singapore to create a PC. While these networks have some characteristics of earlier arrangements, the industrialists creating them believe they are doing something new and innovative precisely because they are using a new kind of production system in a new kind of competition.[39]

These networks *have evolved to exploit an ever more intricate division of labor based on increasing local technical specialization in Asia*.[40] They are not principally about lower wages or access to markets and natural resources.[41] They are, however, about the linkages among diverse and heterogeneous economies.

Such arrangements were, of course, used prior to their adoption in the electronics industry. For quite some time, in industries like garments, footwear, furniture, and toys, it has been established practice for "brand name" companies to depend on CNPNs for essentially all of their manufacturing requirements. For example, US brand name apparel and footwear companies have been utilizing a disaggregated industry structure to create non-equity-based production networks on a world scale since the 1970s.[42] By contrast, disaggregation and production outsourcing did not begin in earnest in the electronics industry until the mid-1980s, a trend that has increased dramatically as the 1990s have progressed. The emergence of contract production and cross-national arrangements in consumer durable sectors such as electronics and now, perhaps, automobiles as well, turns the phenomenon from one of marginal interest to one of real significance. Instead of being confined to essentially labor-intensive low or middle skill products in mature sectors, CNPNs now touch the core elements of the industrial economy and the most rapidly expanding sectors.

The new production model is increasingly pervasive in electronics. Its scale and pace of development is suggested by the rapid growth of the most visible manufacturing network service companies. They have grown over the last decade from a marginal to significant industry segment accounting for over $40 billion in sales in 1995.[43] The top ten firms grew last year by over 56% to almost US$10 Billion. Some estimates suggest that such firms now represent 10-20% of total product-level electronics manufacturing, (up from less than 5% in 1982) and 40-50% of highly volatile electronics industry segments, such as PCs and modems. Firms that provide global scale manufacturing services, such as SCI Systems and Solectron, now produce on the scale of the MNCs themselves and are growing extraordinarily quickly, in part by purchasing customers' formerly captive (i.e., vertically integrated) facilities. For example, in 1986 Solectron generated $60M in revenues and had all of its production capacity in Silicon Valley. By 1995, the company had grown to more than $2B in revenues and had plants in North Carolina, Washington State, Texas, Malaysia, Scotland, France, and Germany. Conversely, former vertically integrated assemblers like IBM, Hewlett-Packard, and Apple have disposed of captive production facilities and moved to the new CNPN model. By 1994, 50% of HP's 20 million circuit boards and 11% of its 4.5 million final products were being assembled by contract manufacturers, as was fully 50% of Apple's production.[44] And some of the newest and most successful systems companies own *no* internal manufacturing at all. Examples include Dell (PCs), Silicon Graphics (workstations), Cisco Systems (networking), Diebold (automatic teller machines), Digital Microwave (communications), Telebit (modems), LAM Research (equipment), and Octel (communications).

In all of these cases, the move to CNPNs and contract production services permits system firms to concentrate on Wintelist product definition and market strategies while conserving capital and gaining production flexibility. The implications are that Wintelism creates a whole range of market opportunities in sectors that were previously dominated by assemblers, often playing in controlled oligopolistic markets. The new CNPN possibilities provide producers with a cost-effective production strategy to exploit the new market opportunities. In short, as Tim Sturgeon concludes, to the extent that network production structures have emerged in a wide range of localities, are highly capable, and have developed an open, "merchant" character, an infrastructure for the implementation of global production strategies *without* FDI has been put in place.[45] Supply chain management, which includes outsourced production and assembly of components, subsystems, or even entire products, begins to replace the notions of vertically integrated manufacturing. Tactical adaptation evolves into strategic weapon. Companies increasingly must define for themselves what links them tightly to their critical customers, what constitutes their core business, and sustains their ability to innovate and maintain that business in the future.

Wintelism, and the outsourcing it embraced, emerged as a model partly as a conscious matter of strategic opportunity and partly because old ways of doing things weren't working anymore.

Part IV. Manufacturing in a Digital Age

The new consumer electronics was an interlude; a precursor to the digital era. Two issues that lead into our discussion here stood out from this "Wintelist" phase of industrial development. First, even as Japanese manufacturing innovation and systems of production networks in Europe were showing how manufacturing could be a strategic weapon, networks of commodity production were evolving in electronics and in Asia in particular. Put differently, manufacturing outsourcing moves from defensive tactic to fundamental strategy. Production networks organized to service American companies on the defensive from Japanese production innovation discovered they had significant advantages in flexibility, speed, and innovation. Contract manufacturing and supply chain management became significant competitive weapons.[46] Second, product functionality rooted in software, digitally created value, was becoming critical to an ever-wider array of goods. If software functionality, digitally created value, is critical, does that make manufacturing a readily available commodity, and hence of limited importance for a company in differentiating among products, and of diminishing importance in the final value of the product? Have the location and mechanisms of market control and value creation shifted in the digital era? The notions presented here are intended to begin that discussion of manufacturing in a digital era, balanced between its function as a commodity and strategic weapon.

As we shall see in a moment, the digital era is constituted by a set of information technology tools," tools for thought ". Business models both consolidate and intermediate the influence of these tools on the strategy and organization of firms. Or put crassly, how do the digital tools influence how companies make money and the ways they must organize to do so. What is to be made within the confines of the firms, what is to be outsourced, rest in turn on how markets are organized and work. We must emphasize again that the critical issues are not about the continuing shift from "manufacturing" to services. The old categories of service and product are simply even less useful in this digital era than they were before, and they were distorting to begin with. Wrongly constructed categories distort our thinking and blind our sight. The very meaning of what a "service" is and what a "product" is changes character in a digital age. The distinction, which was difficult in the first place, loses further value.

As we recall our early examples, Quicken and pharmaceuticals, we see why. In the case of Quicken, a service turns into a product, and then, arguably back into a service. Accounting was a straightforward service, in many cases outsourced to accountants or accounting firms. Quicken put the technical capacity to manage the numbers into a box. The design of the software product created the capacity for the average individual to perform reasonably sophisticated accounting functions. For the small business or the household Quicken captures accounting expertise in the code and expresses it on the computer. However, Quicken is a tool, in some sense no different than a pencil, paper, or calculator. Because it is a widely sold product, the development cost of the tool is, therefore, shared across a widely sold product. More importantly, it powerfully alters the organizational location of the activity. However, for many firms Accounting requires more sophisticated capacities than are embedded in the Quicken product. Some Web companies now offer accounting tools on the Web, as Application Service Providers (ASPs). Companies purchase on-line access to these service tools to provide themselves with even more sophisticated in-house services. We might quickly agree that Quicken, as "accounting in a box" is a product. What is an ASP? It is a web site, a set of servers with rules and data storage capacities. It is not a person-less service, for there are ASP employees, but it is a person-lite service.

But how do we categorize the activity of building the web site? Is the web site a custom Product? It might be a product if sold by a web development company. If a web-development company builds it, is that company selling a service, the service of building the web site, or a product, the web site? However, if the ASP activities are counted as services in the national accounts, then the web site is accounted as a service activity if it is built in-house by the ASP service-company. In any case, the valued added is entangled with the software, whether or not the software is a Product or a Service. We are back to the old national accounts accounting trap we discussed earlier; the categories freeze our thinking.

The pharmaceutical case goes the other way.[47] A product is turned into a service. The ordinary business model is that doctors or other health service professionals provide the services; they direct patients or hospitals to purchase products. But what happens as drugs, and therapies, becomes more and more custom-made. Then the drug company finds itself in the service business as its computers custom design products. The business models would have to change. For example, strategies for market control based previously on patent portfolios, would have to change to models based on perhaps copyright algorithms or trusted relationships with health care end providers.

Business models spell out a particular understanding of how to approach demand, of who wants what, of what creates value and permits marketplace control. What these cases suggest is that as the border between products and services blurs, traditional business models will be challenged and new business models constituting new understandings will be created. Sometimes business models will change; existing business models will be defended by fiddling with the rules of property and market to contain the disruptive impacts of technology. Indeed, the Napster case is one scene in a story of changing business models. It was so provocative, and failed, because it showed the weakness in the old model without providing even the outlines of a new alternative. Digital tools do change the mechanisms of reproducing and distributing entertainment content; the music story could just as easily apply to movies or books. Music and movies have been distributed to consumers as products (CDs or videos) or as services by integrated media broadcast companies, radio and television, or the film industry. Suddenly those models are transformed as the product is transmitted in digital form and the function of TV and Radio channels as intermediaries is undermined. The focus of the debate about Peer to Peer computing has been on the fight over the rules of Intellectual Property as the mechanisms of reproducing content change. Yet in the longer term the real question is what sort of new business models will emerge as the traditional models become harder to defend. The real IP fight is over who provides -- and who benefits from -- the new service distribution mechanisms, and further, what those new mechanisms and business models will be. We should note that the media industry effort to protect its existing business models by entrenching them in IP law have very restrictive implications for the use of information in the society as a whole.[48] Indeed, the very rules of information in our society may be settled, whether we intend that or not, by struggles over digitized media content.

The relevant questions, therefore, are how creating Value and market/product Control are changed in a digital era. The experiments that create the answers will be reflected in competing business models. Before we address that, though, we must ask ourselves what makes the digital era distinctive.

A. Unpacking the Digital Revolution

Unpacking the influence of the digital revolution on production is no simple task.[49] We start with the obvious, the digital tool set, and then we ask how those tools are might influence business strategies. The role of production derives from that discussion.

The Digital Tool Set: the digital tool set, the "tools for thought", on which the dreams of economic transformation and business revolution rested is the critical starting point in any story.50 Information technologies, data communication and processing technologies, are tools to manipulate, organize, transmit, and store information in digital form. These tools for thought amplify our ability to use and apply information; they amplify brainpower in the way the technologies of the Industrial Revolution amplified muscle power.[51] This evolving sequence of "tools for thought" has, quite obviously, altered the way we communicate, entertain ourselves, use information, produce and develop products, and generate and store knowledge. Certainly, this tool set permits new information products, from digital music to customer information by changing the production and distribution of more traditional goods (and services). Indeed, as in our example, it turns services such as accounting into goods such as Quicken, and alters the markets for both information goods and traditional goods. In essence, the tool set changes how information is found and prices are set.

Let us note two features of this tool set.[52] First, in a digital information era most information, whether it is media or engine controls or biological instructions, can be represented in a common form, in the binary alphabet of 0s and 1s that underlies information technology. Thus, at the core of the digital era lies a single innovation stream resting on a common core of information theory and its electronic expression, if not literally a single set of tools, can be used to manipulate a variety of information applications. The set of "tools for thought" rests on the ability to represent information in that digital form, that alphabet of 0s and 1s. Historically, forms of representing information have been in fact analog representations. The original telephone transmitted voice as an electronic wave, an analogy to the voice, converting sound to electronic wave expression then transmitting and reconverting that to sound. The telegraph provides a second, and distinct, analog system for information representation. Digital representation of information differs from its predecessor, analog representation, in that all digital representations have a common foundation and hence can share common tools and infrastructure. Analog representation for each form of information or application requires several sets of tools and infrastructures. The infrastructures for the several information technologies have consequently been separated: a telegraph system, a radio system, a television system, and a telephone system. Let us repeat, but now put simply, the “tools for thought” rest on the ability to represent information in digital form, mostly in languages that are built from a mathematics of 0s and 1s that themselves rest on the binary representation, and that permits electronic manipulation in the states of “on” or “off”. The information age rests on this common digital expression of information.

Second, this set of information tools is increasingly integrated and networked. It is that expansion of the capacity to interconnect the tools, the data sets, and the networks of information themselves that gives the Internet Era its power and flavor. The Internet is conventionally described as permitting the interconnection of a series of otherwise separated networks, either corporate networks or national data networking systems. That integrated information system, linking all forms of information, is possible not only because the several information applications of are expressed in a common way and manipulated in a somewhat similar fashion by a conceptually unified set of tools, but because information can increasingly be transmitted according to a single protocol that permits the multiple tools and networks to be interconnected on a stupid network in a neutral fashion.[53] The internet, we must recall, in the end is a set of rules by which information is exchanged, including the guarantee that what was received was what was transmitted, the bits sent are the bits received or at least you know that a piece of the transmission is wrong. These Internet rules, or the TCP/IP (Transmission Control Protocol resting on top of the Internet Protocol), facilitate the network of networks that permits the network integration in the information system. This interconnection is a choice, not, of course, a technological inevitability but a socially agreed fact.

Data networks had been in place for large companies, but generally configured as relatively closed private networks organized by the particular company or provided by a network provider to a single company or discrete set of companies. The real internet revolution was based on three innovations: the network protocols that allowed interconnection (TCP/IP), the browser technology that gave a user interface to the networks, and the addressing system of the world wide web (WWW) that allowed easier communications among those on the network. High speed data network connections were ubiquitous, that is widely and easily available, permitting simpler interconnection of computer systems with facilitating tools that made the network of networks faster and more convenient to use. Indeed, these tools made the networks possible to use for small business and individual consumers. The sudden spread of data networks to a consumer and small business community launched the dot com chapter in the e-commerce story. That "chapter" focused on the connections between business and consumers, the b-to-c story as it came to be called. It also altered the way companies could link to their suppliers and business customers, the so-called b-to-b story.

Two examples clarify this point. First, the result of integrating tools and networks is the not utterly impossible parody that with integrated networks and shared processing a smart toaster in Berkeley might actually control a tank in Afghanistan. Here, control via the network is the key notion. Second, what we can know about whom on an ongoing basis is changed by microsensors, wireless networking, and distributed super computing. With networks of microscopic transmitting sensors science fiction possibilities become the substance of conventional sitcom. Consider "smart-dust", microscopic sensors that are under development at UC Berkeley. Mix those sensors into aftershave or face cream. Then you can transmit physiological responses about what someone is doing that can be matched with information about location soon available from the mobile phone. In any case, that system, that network of networks, has a structure or architecture that shapes what is possible and what is not. The reality is that webs of information are created, transferred, manipulated, turned into product, shared and sold.

B. Information, Strategy, and Production

The emerging digital tool set and networks mean that information in a digital form becomes critical to firm strategies to capture value and market position. The word information needs meaning or else it refers to everything and nothing. Let us use the modest notion of information as a data set from which conclusions can be drawn or control exercised rather than the more glorious notions of knowledge, the result of learning and reasoning, or intelligence, the ability to comprehend and use that information. How then do we approach the underlying question in this essay, whether manufacturing still matters in the era of digital networks and digital tools? We can rephrase that question to ask what competence or capacity at manufacturing must a nation or firm has in manufacturing in order to sustain growth and productivity. We begin with questions about the place of manufacturing: 1) in creating value; 2) in holding and controlling the know-how and knowledge on which value and market position rests; and 3) sustaining innovation. By the end of this section we will have abandoned the word, manufacturing, and adopted the term, production.

We do not require a review of business strategies, but rather a flavor of how shifting strategy affects the place of production in a business. Let us consider several consequences of digital tools to capture the flavor.

First, how do digital tools influence what the market is? How do we know who the customers are, what those customers want, and when? Markets are increasingly segmented as data mining tools plumb the information about consumers. Markets are segmented by ever more refined demographics and preferences, of course, but also segmented by time of day or in a person's life. Markets can be imagined as streams of consumption over time. When your child turns sixteen, the insurance company can send you offers of auto insurance, for example. Hitting the sweet spot in the market depends on gathering and mining customer information. This is as true in finance, where insurance or credit card offerings can be customized, as in printers where different performance commands different prices. Knowing the topography of the market generates the need for varied product offering to address a mass market that now appears as an assembly of niches.

Two, product functionality is increasingly defined by digital technology. That is true not only for the sectors such as finance and media where the product can be entirely and delivered over networks and through network based markets, but for traditional services and products as well. In finance, the product is created not in the plastic we carry or the insurance policy we read, but in the computers and servers that define what the "product" is and how it will operate. Indeed insurance was an early user of mainframe computers to create varied new products. In that insurance and finance are, at their core, information, they, like media content can be purely digital products. Money becomes nothing but a "bit" on a hard drive within a set of coded rules. Indeed, parts of the marketplace itself can go on line.

Third, a market defined by diverse niches raises the obvious question of how that product variety is achieved. A very early example and extension of digital functionality is product versioning. Digital tools can create a range of product versions, not only for purely digital products that are themselves principally information, but for traditional products as well. Versioning is not new; functional variations defined by digital means are new. Henry Ford, we are all told, created Mass Production. General Motors transformed the automobile market into a series of segments by using several brands each aimed at different sets of customers. The variance in underlying technology and cost was often much less than the brand differentiation suggested or the price commanded. Japanese production innovation in the 1970s and 80s created competitive advantage by facilitating flexibility in the existing range of product and rapid introduction of new models over time. But the models did require different assembly lines, parts, paints, and interiors. What differentiates a fast printer from a slow printer? Often the electro-mechanical operations are identical, even the fundamental microprocessor controller. The variation is in the instructions built into the controller. As Shapiro and Varian note, in some cases the instructions in the slower, lower cost printer, simply tell it to go slower; in other words, it is the same printer forbidden by its makers to go fast.[54] This is "commercially crippled software", or a sophisticated kind of price discrimination.

In each of these instances data as information about the market or as a means of controlling and giving functionality to the product – was at the core of the creation of value. Information tools created the product value by identifying how to segment the market, generating functionality, and creating the product customization through digital versioning. That has led to the correct notion that information and knowledge are central in the story, to next generation business models and business strategies, and to the less evident conclusion that manufacturing is of reduced importance.

<u>C. Production in a Digital Age: Intellectual Property, Innovation, and Product Control</u>

We begin our assessment of the digital era by considering how digital tools permit sophisticated and nuanced market definition, digital functionality, and product variability. These issues lead to our critical question. Where does production fit in this story, indeed what is production, what is product development, and where is the borderline? Has manufacturing simply become a commodity of no particular importance in an era in which functionality digitally defined? Or better, when is manufacturing a commodity, a tactical consideration, and when is it an essential strategic part of product/process realization and innovation that creates distinct market advantage? If that role – commodity or strategic development weapon -- fluctuates between commodity (the American automobile big three in the 60s and 70s) and strategic weapon, (Japanese producers in the 80s), will it be critical for a firm, or a country, to retain production skills and capacities in the 21st? Can production skills and manufacturing capacities once given up be recreated?

How do we go about answering that question? Return to our brief recounting of the stages of production development in Section 2. The assembler in both mass production and lean production dominated the relationship to the marketplace. The capacity for production innovation, the ability to ever improve the capacity to manipulate physical materials was critical within the boundaries of the firm. In the era of Wintelism, outsourcing took on a different meaning, a strategic means of accomplishing production. At one point in this era the debate became when did outsourcing, which had tactical advantages, create strategic development weakness. Dell, which uses distribution and market knowledge to dominate the relationship to the market, is a symbol of the debate about how outsourcing can become a strategic weapon. Dell's supply chain management is a critical element in its competitiveness, but the actual manufacturing is external.[55] But we should move slowly. Conversely, HP in defending its Ink Jet market years ago found that control of the production process was essential. Japanese firms had used manufacturing cost advantage to enter the low end of the market and then migrated up market. In a range of sectors from TVs through cars the story repeated itself. Once entrenched with production skills and then distribution, the Japanese firms moved, and were induced by American trade policy to move up market. For American firms to stop the cycle by which Japanese firms entered the American market at the low end and then moved up market, they needed to challenge the initial entry. HP chose to do that, using domestic production skills to both maintain their low-cost position and to migrate through product generations rapidly. Could HP have been able to accomplish the same strategic purposes with off shore assembly? Is the contract manufacturing industry sufficiently developed now so that HP could dictate to a contractor the strategic objective and expect a contract provider to be able to innovate in production sufficiently to accomplish that strategic goal? Certainly the capacity to ship information around a production system contributes to the ability of semiconductor firms to focus on design within given technological constraints, and the system of contract production (fabs and fabless design houses) is sufficiently developed for the design houses to thrive.[56] The underlying production technology in the semiconductor industry is defining parameters within which the design houses can work.

One response, of course, is that the strategic skills become the management of the supply chain and its orchestration into virtual vertical integration as a strategic weapon. That may be the case of a company like Dell which is able to link its marketing to its supply chain management both operationally and strategically. It does though beg the question of whether there are parts of that production process or supply chain that should be kept within the company, or rather what can be safely outsourced for tactical advantage and what creates strategic risk. We ask, what might be lost, and how, from outsourcing production? How, we must ask, does the decision about business strategy, a bet on what is critical to the company's enduring position, influence that conclusion. Several issues are raised. *First*, when product and production knowledge is formally expressed in transferable digital code, the enduring questions of formal Intellectual Property and implicit know-how are opened anew. When knowledge about product and production can be formally stated, and indeed, transferred in digital packages, it is vulnerable to being captured through copying, re-engineering, or theft. If product functionality and production processes are formally expressed in code, then defense of that code, that formal expression of function in code, becomes critical. Whether the product is a semiconductor, where the critical information is the depiction of the mask sets that create the chip, or an Internet router, where the instructions in the chip set define the function, the enduring problem is how to protect the formal knowledge.

Formal expressible knowledge must be defended, and a variety of mechanisms in organizational practice, business strategy, and legal defense are necessary. Cynically in some sector the question must be asked, does the reality of formal knowledge and easily replicable digital product force changes in business model or the law of intellectual property. And are those changes in the IP law really necessary and productive, except to a few established firms. Evidently, one way to do it is with the legal instruments of Intellectual Property. Patents and copyrights become more central as the amount of expressible knowledge grows. But an alternate approach remains, shown to us by Coca-Cola, which reminds us that trade secrets are an alternate approach. The coke formula once "cooked up" can't be resolved into its individual parts; the process can't be reverse engineered from the product. In an important sense, neither can computer code. If source code is protected from prying "others," it cannot easily be reverse-engineered.

But informal and implicit know-how does not lose its significance in this digital age. Much of the digital world is also protected by the implicit knowledge embedded in the complex system that most programs present. In an electro-mechanical era much of the knowledge of product functionality and its development is embedded as organizational know-how, or groups of people who know how to do tasks that individuals could not do on their own. Entire production systems include both the formal knowledge of a product design, component specification, or tooling characteristics, but the subtle know-how of how they are combined together is in teams of people and larger organizations. That is equally true with complex systems projects and code systems. In one sense they are protected by the privacy of the "formula" - in computers - the privacy of source code. But if the formula or the source code were stolen, how much of the process is rooted in a particular organization's know-how, and consequently not replicable. As we see in a moment, part of the digital world, the open source community, represents a radically different approach to production organization and intellectual property.

There are, evidently, a variety of implications. The character of outsourcing relationships is influenced by the degree of tacit knowledge in product and production process. When a firm must strategically outsource an element of the production chain that embodies a high degree of tacit knowledge, then it requires inter-company relations with permanence and continuity. One certainly is that the greater the degree of tacit knowledge in a product or process, the

Second, how are the processes of product innovation and firm organization affected by the formal digital expression of information and knowledge? One way of expressing this is to ask, does digital technology affect where the learning takes place, in the supplier of a component or the semiconductor chip where the code is housed or expressed? Consider that with many communications technologies what are becoming standard, i.e. shared across a community of users, chip sets are shared amongst several companies each competing to sell products that depend for function on the chip set. Is the code that creates function different with each competitor? Not always. What differentiates the product? It is not clear, though in part service and support. In which case has a product manufacturer become a service company? Sometimes the company itself is divided. But the development costs, and the risks of getting to market initially and staying a course of hardware innovation, are much great if the chip set is specific to one user. Hence a complex dance of how the IP and application know-how is generated and captured. Next generation product development in sectors may well depend on a knowledge of the possibilities of both the semiconductors which define how code will operate and the design tools which specify how the chips function. But when does a firm require that knowledge be in house, in the form of design and production expertise. Knowledge of next generation chip technology, the base on which chips are built, is required; but if that knowledge is available in a competitive marketplace as a product and perhaps even a commodity, is that sufficient? The critical product knowledge may be the adaptation of software to a chip set. The critical market knowledge will usually not, for a component maker or capital goods manufacturer, be the aggregate information in a data set, but the nuanced information of the sophisticated lead user who can help define the product and identify problems as it evolves. How does the recognition that the strategic processes of learning are influenced powerfully by mastery of production and product, affect the decision of which activities to keep within the firm and which to source outside?

D. Production in the Political Economy of the Digital Age[57]

Let us approach this problem of production in a digital era from a different angle. Does the process of creating value and governing the production process (let us set aside distribution) change in the digital era? The answers to these questions must turn on a strategic view of what defines a company's core business and establishes the capacity to capture and hold critical customers.

From Mass Production to Distributed Innovation, *The Evolution of the Division of Labor:* We have considered an array of production types that embody organizationally distinct ways of creating a division of labor. Consider first that the archetype of the industrial era is the division of labor in Adam Smith's pin factory. Here the production of the classic good, the pin that had been made by a craftsman is now made by an "industrial" process. The capitalist sets the process and the divisions of labor, assigning tasks that subdivide the process. The archetype of the digital era may be open source software, a system of distributed innovation where tasks are self-assigned and where even the management of the innovation is voluntary.[58] The two systems of political economy rest, moreover, on quite different notions of property. Perhaps the enclosures were the archetype of property in the great transformation; the right to exclude you others from using what had been a commons. By contrast in a distinctive style of the digital age, open source software hinges on a different notion of property. Steve Weber writes:

> Property in open source is configured fundamentally around the right to distribute, not the right to exclude. If that sentence feels awkward on first reading, it is a testimony to just how deeply embedded in our intuitions and institutions the exclusion view of property really is.[59]

Open source software is a story of capitalism; it is a story of how intellectual products are created and how new business models are generated from that process. New processes of development, such as Open Source software which hinge on a formal statement of knowledge but virtually voluntary tasking within defined legally enforced rules about how the product of the efforts may be used, set up an alternative to established ways of organizing production activities. A political story of the digital age is one of how this process seemingly doomed to chaos is managed with such brilliant success that Microsoft considers itself threatened.

Open source is, without doubt, a system of production, an organization structured to produce things. Are such arrangements possible without the digital mechanisms of communication and information sharing? Almost certainly not; that is, these mechanisms of cooperation are a true product of the digital age. Could these arrangements and conception of property as the right to distribute has emerged except in the development of code based products? Again, almost certainly not. Could the production approaches be applicable in a wider range of approaches, now that the mechanisms of management are clear? That is another matter altogether, with no answer to date at all.

We might imagine a spectrum that begins on the left with the division of labor and the classical pin factory of *mass production logic.*

Mass Production Logic → *Distributed Innovation Logic*

←——————————————————→

[60]

On the right is what we will call *distributed innovation* that is exemplified by open source with its distinctive notions of property as the right to use and distribute. What drove the move from a logic of mass production to distribution innovation? In the case of the Japanese, efforts to construct a mass production system in a society composed already of small and middle-sized firms created the pattern of controlled but virtual vertical integration that contributed to the lean production model. [61] At the same time communities of producers in parts of Europe were establishing distinctive approaches to production, innovation, and global markets.[62] American firms without internal capacity for flexible production reached outside the nation, as well as to production service firms to solve their problems. [63] At the same time, of course, the diversity of technological strands required in modern product compelled outsourcing production, and indeed outsourcing innovation in the form of strategic venture capital, acquisitions, and strategic partner relationships. [64] Let us consider three elements in the middle that provide a theoretical, and perhaps an historical, bridge.

Someway from the left on the spectrum we might fit *'lean production'* which enabled the factory floor. It is an inductive production process rather than one that dictates things from the center. Individual elements in that process though remain in a clear national hierarchical structure orchestrated by the assembler with market position. Further to the right on the spectrum we find *flexible specialization*, in its classical form (see the distinction made above) a community of producers in which authority, hierarchy and community blur.

To the right of the flex spec model, we would situate the Cross National Production Networks (see section 3), which have the flavor of a system of distributed innovation. What distinguishes this from the hierarchical system of lean production with its several tiers of producers? The final assembler in CNPNs is a "service" company that provides a production service to another company whose brand is going out to the consumer. Of course the final producers, the contract manufacturing company may try to accumulate the market and design skills to displace its customers. That is of course a risk. The individual companies, moreover, are trying to extend the range of their activities, taking more design or a subsystem as their responsibility. And many of the producers are backed by national or regional government efforts. Since the individual suppliers are distributed across a set of countries, (hence cross national production networks), a set of distributed efforts at innovation are at play. Hence we would label this system "enhanced developmentally enabled division of labor".

Reconfiguring and Extending the Notion of the Value Chain: The next notion we should explore is the extension and reconfiguration of the value chain. Distinctions are blurring among steps in that value chain traditionally conceived as separate must change our understanding of the place and role of production. First, the line between development part of R&D and traditional production erodes when new products continuously require dynamic adaptation of production processes. Again, lean production, we are continuously told, is system of continuous innovation and adaptation of the production line, rather than the traditional approach of mass production system which moves in a manner specified at the top, from one "plateau", one production system, to the next. In the same sense, we have depictions of new products in which development and pilot production go hand in hand, after which the product pilot line is handed off to a contract manufacturer. In that sense, the development phase suddenly includes the original pilot line, not just a handcrafted demo product. Similarly, with radical breaks between product generations, with new technologies obsolescing old capacities, the R&D process reaches outside the firm. Indeed venture capital suddenly plays the role of specialized alternate lines of technology and development that can be drawn into a product line by a larger company or integrated into a product offering. [65]

What all this suggests, we are all clearly aware, is the limit of the traditional notion of a value chain as a linear process resting on a social infrastructure and responding to or realizing itself in consumer demand. We often talk as if there were sharp distinctions between "social infrastructure" proceeding the commercial division of labor, demand, and consumer markets, following it. The distinct steps, we argued above, blur as production becomes part of development. Development then becomes a network of connections as the venture-financed technology-company becomes a conscious instrument of company policy

Sophisticated final users, lead users, we have long been told are critical to development. Company ties back into the science and science-based engineering research community, at home and abroad, are critical both for large firms and those spinning out of the research community.

As important, as science-based engineering evolves and new technology-based sectors emerged, the political choice to reinvest in that social infrastructure becomes critical to regions, governments, and companies. Consider the efforts at any major research university to continue to develop electronics and biotech laboratories with public and private money: a company like Chiron, the bio tech firm headed by a former Berkeley professor later to become Dean; or a company like Cadence, the semiconductor design tool firm resting on the work of critical Berkeley faculty

E. Sectoral Vantages on the Problem of Production

The answer to the question, what place for manufacturing, almost certainly, will vary by sector. As a way into this discussion let us divide matters into three sets:

- Digital functionality/digital markets
- New processes and new materials
- Conventional products

As we argued at the beginning, we are wobbling in the use of the word production and manufacturing. That is intentional. Manufacturing has come to imply the old economy, the manufacture of physical goods in factories. Now, the creation of a product takes on a broader meaning, hence the notion of production as the creation and making, sometimes integrated distribution, and initial coaching (a service activity, of course) in the use of a product.

Digital functionality/digital markets: In these sectors product, production, and the marketplace are altered. Old approaches, old business models, come under intense pressure. We begin here because it poses directly the fundamental question; what is manufacturing in a digital context? For our purposes we can define two sets of "sectors" that have digital functionality. For one set of sectors, such as finance and media, both the product and the marketplace could be in digital form. For others such as computers or telecom equipment, the core functionality is the information or data processing. For both, the hardware is a simple instrument for the digital material. In the case of a car or refrigerator the IT instrumentality creates distinct controls and adds value. Yet, the underlying purpose and the source of functionality, transportation or refrigeration is something physical and not digital.

Pure software products, be it a Windows operating systems or the web structure for delivering an accounting service, are built. While manufacturing implies manipulating things and materials, its definitions in my on-line dictionary more generally talks of "the organized action of making goods and services for sale" and putting something together from components and parts.[66] Certainly our example, Quicken, qualifies as manufacturing by this definition, as does the creation of the Yahoo web site, and the assembly of the software tools that allow that web site to function.

But the word manufacturing implies smoke and factories. We require a new word, stripped of the grime of 19th century manufacturing. It may not be possible to tilt the usage to fit the concepts we are developing of a word, manufacturing, already loaded with centuries of accumulated meaning. But why not just talk of production as the general case, and manufacturing as the specific case of physical production? In that case, production – the know-how, skills, and mastery of the tools required -- is absolutely central to the products in the sector. All the arguments about the linkages and mastery of groups of activities that we developed in the first section of the paper then would be revisited.

The critical question, once we acknowledge that software production is a form of manufacturing, is what are the most effective ways of organizing software production.

The list begins with the conventional question of whether to outsource or where, geographically, to locate software development. The story becomes interesting when we ask whether to choose conventional hierarchical production structures typified by Microsoft or new alternatives such as the commercialization of Linux products developed in an open source model.

Many of the same issues arise with products such as computers or Internet routers where a digital processing lives in a hardware house. The digital functionality expressed through the hardware differentiates the products. The issue, which is distinct from our pure software products, is what hardware knowledge is required to effectively implement the software solutions. Is the semiconductor a commodity, as it is for Dell in a PC, or a proprietary chip as it may be for some telecommunications applications, or a specialty chip shared with other producers? That answer depends on the particular product and the particular hardware environment. And there is no consistency to the answers. Dell outsources its actual manufacturing and assembly, making its supply chain management into a strategic weapon. Dell's market link is the key; it has no distinct product knowledge. Cisco likewise outsources production, but its distinct product knowledge is in the development of generations of equipment in which functionality is expressed through electronic hardware but determined by software instructions.

Clearly, the meaning of manufacturing, or production, changes as software becomes more important. At one point a central office switch cost tens of millions of dollars to develop and several thousand workers to manufacture. Then by the early 1990s, the development costs became a billion dollars, but with semiconductor, board stuffing, and automated assembly the manufacturing could be done with a few hundred people. Early versions of routers and Internet access equipment were really honed when the product was already in the field in the hands of very sophisticated early users, universities and early Internet Service Providers. And there were serious mistakes with stories of early product catching fire because heating problems were not resolved. In any case, if the product must work first time out for more conventional users such as telecom companies, the lines between development, production, distribution, and support vanish. Consequently, the manufacturing solution can be workable at the beginning. Is assuring the product will work at the beginning of the cycle a design and development problem which can then be handed over to contract manufacturing folks, or does that design and development expertise require hands on internal production of the hardware?

New processes and new materials: We treat new processes and materials as a distinct separate category. Consider three such instances – nanotechnology, bioprocesses, and open source software development. *In these sectors the question of production, product innovation, and market control remain entangled.*

This 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 knowledge and techniques, by purchase or parallel internal development perhaps conducted by newly hired skilled employees? What happened in semi-conductors development was that at a moment of new technology development, the when two major dominant established players – IBM and ATT – were restricted by Anti Trust competition concerns from producing semi-conductor products for sale in the merchant markets. But the Anti Trust ruling was critical to that outcome, and to the emergence of the merchant semiconductor firms. That merchant sector changed the course of the Information Technology evolution worldwide.

There are a number of ways of approaching an answer to this question; arguments that begin with transaction cost economics, arguments that begin with notions of tacit knowledge, and political arguments that suggest national boundaries and security concern will dictate the outcome of how the new technologies are exploited. Now it is only important that we flag the issue.

Second, with new process and materials, new kinds of production skills become essential. As new processes or materials emerge, it is harder to find the requisite manufacturing skills as a commodity. And moreover an on-going, critical interaction is needed, 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. 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 or possible at all through arms-length marketplaces? For the nation or region, the question is whether ongoing production activity is needed to sustain the knowledge required to implement the new science and science based engineering. In other words a regional or national government may not care if the learning goes on within a specific firm, as long as the learning is captured in technology development within its domain. Those intimate interplays have traditionally required face-to-face, and hence local and regional, groupings. With the new tools of communication, what happens to the geography of the innovation node is an open question.

As argued earlier open source software development represents a new production method. Open Source software, which hinges on a formal statement of knowledge but virtually voluntary tasking within defined legally enforced rules about how the product of the efforts may be used, overturn established ways of organizing production activities. And we have not yet begun to think through the implications.

Conventional Products with Digital Functionality and a Physical Function. Conventional businesses are likewise altered by the digital tools. And as much within the set of conventional product as elsewhere in the set of digital products and tools of the information era, the underlying business models that hold together the diverse activities of the firm are powerfully influenced. Digital controls/sensors are adding value and functionality to a wide range of products from cars to refrigerators. We do not need to review examples. The question is whether those controller/sensor systems are commodities and whether adding them to a conventional product with a physical function changes the outsourcing decision. HP used manufacturing to stand off the Japanese challenge. In other cases, development and initial manufacturing were linked, with production outsourced once the product stabilized. In cases we have already discussed, both the ink jet printer and the central office switch, there are two processes. There is the production of the initial final product, a step beyond prototype, and the volume production once it is stabilized. Indeed that line is often blurred.

The range of products is too great to be put into a single set. Questions that must be answered in each case, though, are

- What is required to implement the digital functionality?
- Is a proprietary position required and can a propriety position be developed with outsourced digital development of hardware and software?
- How much knowledge is now derived from production? Is it possible for rivals to enter the market based on their learning from producing?
- Without production, how is innovation in the core product affected? How much production knowledge is required for next generation efforts?

But even these questions are conventional. We might ask an altogether different set of questions; when do the new tools alter fundamentally the underlying business models on which firms operate? When does market knowledge and communication tools transform a product business into a service business. If product upgrades or control functions dedicated to specific problems can be achieved through network connections, transferring data or downloading applications, then products and production can become part of a service business. If production becomes characterized by rapid turnaround and custom activity is the decision to about where to locate production within the firm changed. More precisely does custom production and rapid turnaround imply tighter geographical and organizational links between production and development?

The answer to these kinds of questions may be different for firm and locality since the firm may be able to obtain critical knowledge outside its organizational boundaries. The nation or region may require that expertise to assure sustained innovation and production by a range of firms

Conclusions

This essay examines the place of manufacturing in an emerging digital economy. The digital era is defined by a set of tools for thought, tools, data communication and data processing technologies, that manipulate, organize, transmit, and store in digital form information, with information defined as a data set from which conclusions can be drawn or control exercised. The emerging digital tool set and networks mean that information in a digital form becomes critical to firm strategies to capture value and market position. Those tools certainly create new opportunities, but they also provide companies instruments to find solutions to existing tasks. The tools permit mass markets to be segmented as well as creating flexibility and functionality for both information based and traditional products. . But the possibilities create difficulties, threats to existing business models and established players. As an example, consider the media industry, which found that once its products are in an easily replicable digital form, despite technology and law, it is difficult to retain control of their commercial distribution. Business strategies and organization, the business models that define the links between objectives and implementation, have all evolved in response to and in implementation of these tools. And with that evolution, the meaning, not just the role, of manufacturing has evolved as well. We argue that in order to articulate the place of production in a digital era, we require a new nomenclature, one stripped of the grime of the 19th century manufacturing. We use the word "production," almost a synonym for manufacturing, meaning the creation and making of a good. It need not evoke the more limited sense of physical manipulation implicit in the term manufacturing and allows us to step beyond the current data categories that blind us to the transformation in the productive economy. The term production, as the act or processes of producing something, can encompass a range of products and platforms that provide services. One implication clearly is that both matters of software and supply-chain management are firmly questions of production as much as service, and must be understood and grouped there.

The rise of the digital economy ignites again debates over the reorganization of production in industrial economies. For several decades, analysts attempted to describe the central features of the next economic epoch with labels like the "knowledge," “information,” or “service” economy. The conventional argument claimed that just as an agricultural economy gave way to a manufacturing economy, an industrial economy was giving way to a service economy. Hence, their arguments went, industrial production was of diminishing importance. We have considered the dysfunction inherent in the manufacturing/services distinction. That manufacturing continued to matter with the rise of a service industry was obscured because we were committed to counting, and hence observing, the wrong things. Whether the data can be reformed to match the more useful concept is another matter.

In fact, production was not vanishing but being reorganized. American difficulties competing in manufacturing arose as competitive production strategies emerged elsewhere that forced the re-orchestration of production. With a new label, our discussion steps beyond the service/manufacturing divide and permit a consideration of strategy development and production reorganization in a digital era.

The digital era brings new issues. The digital story and the issues it brings can be understood by beginning with the transformation of the consumer electronics industry that stands between an electro-mechanical era and the digital age. That transformation was characterized by an emerging Wintellist model of competition. Competition in the “Wintelist” era is a “struggle over setting and evolving de facto product-market standards, with market power lodged anywhere in the value-chain, including product architectures, components, and software. Each point in the value-chain can involve significant competition among independent producers of the constituent elements of the system for the control over the evolution of technology and final markets”. In this new era, products like the Intel Processor or the Microsoft Operating System were accessible and open but owned, so that the components, the constituent elements of the system, were open enough that the elements, or new applications, could be interconnected. However, the standards, the Intellectual Property dictated how the constituent elements worked was owned. In the resulting competitive system, the makers of the critical constituent elements rather than the assemblers such as Dell or Compaq dictated the pace of production innovation and market evolution. And amongst the assemblers those such as Dell who were able to link marketing to supply chain management in new ways became winners.

At the same time that competition was restructured, production in this Wintellist interlude was reorganized with tactical outsourcing becoming a strategic instrument of supply chain management. CNPN is a label we apply to the consequent disintegration of the industry's value-chain into constituent functions that can be contracted-out to independent producers wherever those companies are located in the global economy. CNPNs compromise a clever division of labor in which different value-chain functions are carried on across national boundaries by different firms under the coordination either of a lead MNC for its own production or of a Production Service Company (PSC) who manages the production value chain for clients. This strategic and organizational innovation, at an extreme, can convert production of even complex products into a commodity that can be purchased in the market. Fordism was an argument about balancing within a national economy rigid production systems and fluctuating demand. Lean production was about production innovation and the relationship amongst national production systems. Flexible specialization was about community. Wintelism in the end is about the integration of production systems across borders.

"Tools for thought", information technology, does not have uniform implications for all companies. The character of the particular sectors, and more specifically in the role that digital information plays in those sectors, is quite varied.[67] Hence the place of manufacturing, the organized act of producing a good or service for sale, will vary from a digitized market and product, as finance increasingly is, to sectors like transportation where digital tools are employed to produce a physical product. The critical question is whether, or when and under what circumstances, production is a strategic weapon and when a commodity. For example, mastery of production is most important in new products and production processes because there is no commodity knowledge. Dell turned the commodity character of PC production into a strategic weapon linking production to the market. The implication, it would seem, is that it is safe to outsource, and to allow learning to take place in limited ways in companies servicing the final product-company, during ordinary times. But not so fast. Who knows when ordinary times are about to stop. And who knows when radical change may make it important to bring production learning in-house. The digital revolution has altered value creation and control. But it does so differently for sectors that have Digital Functionality and a Digital

Market, those that involve New Processes and New Materials and those that remain Conventional Products with Digital Functionality and a Physical Function.

Finally, the issues for the firm and the nation may be quite different. A firm may not require the skills in-house, but the region may need the production skills to hold a set of firms in the region. One matter we must note in closing but have not developed is that firms and production regions are within nations. Is production available as a commodity? It depends on the politics and political economy of many parts of the world system. Is it necessary, and when is it necessary, to assure domestic skills for the political risk of the loss or denial of production skills in the global market.

References

[1] Daniel Bell. *The Coming of Post-Industrial Society: a venture in social forecasting*. (New York: Basic Books, 1973) Manuel Castells, The Information Age: Economy, Society and Culture. (Oxford: Blackwell, 1996)

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

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

[4] Charles F. Sabel. *World of Possibilities: flexibility and mass production in Western industrialization*. Paris: Cambridge University Press, 1997). Michael J. Piore and Charles F Sabel. *The Second Industrial Divide: possibilities for prosperity*. (New York: Basic Books, 1984). Charles F. Sabel. *Work and Politics: the division of labor in industry*. (Cambridge: Cambridge Univeristy Press, 1982). Michel Aglietta and Brender, Anton. *Les Metamorphoses de la Societe Salariale: la France en projet*. (Paris: Calmann-Levy, 1984).

[5] See John Zysman and Laura Tyson, "The Politics of Productivity: Developmental Strategy and Production Innovation in Japan" in *Politics and Productivity: The Real Story of How Japan Works,* Chalmers Johnson, Tyson, Zysman, eds. (Cambridge: Ballinger, 1989). (Cambridge: Ballinger, 1989).

[6] Wordweb Online Dictionary.

Part III is drawn from the unpublished appendix entitled "Wintellism as an Optic on Society and Economy" to the article "Wintelism" and the Changing Terms of Global Competition: Prototype of the Future." Michael Borrus and John Zysman. February, 1997

[8] The analysis here extends the conversation begun by Cohen and Zysman. Stephen Cohen and John Zysman. *Manufacturing Matters: The Myth of the Post Industrial Economy*. (New York: Basic Books 1987).

[9] James P. Womack, Daniel T. Jones and Daniel Roos. *The Machine that Changed the World*. (New York: HarperPerennial, 1991). See also Paul Hirst and Jonathan Zeitlin "Flexible Specialization: Theory and Evidence in the Analysis of Industrial Change" in J. Rogers Hollingsworth and Boyer (eds) *Contemporary Capitalism: The Embeddedness of Institutions*. (Cambridge: Cambridge University Press, 1997).

[10] Gregory W. Noble. *Collective Action in East Asia: how ruling parties shape industrial policy*. (Ithaca, N.Y.: Cornell University Press, 1998).

[11] Stephen Cohen and John Zysman. *Manufacturing Matters: The Myth of the Post Industrial Economy*. (New York: Basic Books 1988).

[12] Stephen Cohen and John Zysman. *Manufacturing Matters: The Myth of the Post Industrial Economy*. (New York: Basic Books 1987). Benjamin Coriat, "The Revitalization of Mass Production in the Computer Age" paper presented at the UCLA Lake Arrowhead Conference Center, Los Angeles, CA. March 14-18 1990; Ramchandran Jaikumar, "From Filing and Fitting to Flexible Manufacturing: A Study in the Evolution of Process Control" Working Paper 88-045 (Boston: Division of Research, Graduate School of Business Administration, Harvard University, c1988); James P. Womack, Daniel T. Jones and Daniel Roos. *The Machine that Changed the World*. (New York: HarperPerennial, 1991).

[13] Stephen Cohen and John Zysman. *Manufacturing Matters: The Myth of the Post Industrial Economy*. (New York: Basic Books 1988). Benjamin Coriat, "The Revitalization of Mass Production in the Computer Age" paper presented at the UCLA Lake Arrowhead Conference Center, Los Angeles, CA. March 14-18 1990; Ramchandran Jaikumar, "From Filing and Fitting to Flexible Manufacturing: A Study in the Evolution of Process Control" Working Paper 88-045 (Boston: Division of Research, Graduate School of Business Administration, Harvard University, c1988); James P. Womack, Daniel T. Jones and Daniel Roos. *The Machine that Changed the World*. (New York: HarperPerennial, 1991).

[14] Ramchandran Jaikumar, "From Filing and Fitting to Flexible Manufacturing: A Study in the Evolution of Process Control" Working Paper 88-045 (Boston: Division of Research, Graduate School of Business Administration, Harvard University, c1988)

[15] John Zysman and Laura Tyson, "The Politics of Productivity: Developmental Strategy and Production Innovation in Japan" *Politics and Productivity: The Real Story of How Japan Works,* Chalmers Johnson, Tyson, Zysman, eds. (Ballinger, 1989).

[16] Murakami Yasusuke and Yamamura Kozo "A Technical Note," in Yamamura, *Policy and Trade Issues of the Japanese Economy: American and Japanese perspectives* (Seattle: University of Washington Press, 1982).

[17] Murakami Yasusuke and Yamamura Kozo "A Technical Note," in Yamamura, *Policy and Trade Issues of the Japanese Economy: American and Japanese perspectives* (Seattle: University of Washington Press, 1982).
[18] Nobuhiro Hiwatari "The Political Economy of Enterprise Unionism and Industrial Collaboration in Japan" (Tokyo: Institute of the Social Sciences, 1993).
[19] John Jay Tate. *Driving Production Innovation Home: Guardian State Capitalism and the Competitiveness of the Japanese Automotive Industry* (Berkeley: BRIE, 1995).
[20] John Jay Tate. *Driving Production Innovation Home: Guardian State Capitalism and the Competitiveness of the Japanese Automotive Industry* (Berkeley: BRIE, 1995).
[21] Charles F. Sabel, Horst Kern, and Gary Herrigel *Collaborative Manufacturing: New Supplier Relations in the Automobile Industry and the Redefinition of the Industrial Corporation*. (Cambridge, Mass: International Motor Vehicle Program, Massachusetts Institute of Technology, 1989); Charles Sabel *Work and Politics* (Cambridge: Cambridge University Press, 1982); Suzanne Berger and Michael J. Piore *Dualism and Discontinuity in Industrial Societies* (New York: Cambridge University Press, 1980).
Paul Hirst and Jonathan Zeitlin "Flexible Specialization: Theory and Evidence in the Analysis of Industrial Change" in J. Rogers Hollingsworth and Boyer (eds) *Contemporary Capitalism: The Embeddedness of Institutions*. (Cambridge: Cambridge University Press, 1997)
[23] Charles Sabel, "Flexible Specialization and the Re-Emergence of Regional Economies" in *Post-Fordism: A Reader*. Ash Amin, ed. (Oxford: Blackwell Publishers, 1994)
[24] Suzanne Berger and Michael J. Piore *Dualism and Discontinuity in Industrial Societies* (New York: Cambridge University Press, 1980).
[25] This story is most brilliantly told in Sabel's first and magnificent book. It is told again by Sabel and Piori in a lovely synthesis of the analysis and argumentation of two talented scholars. Charles F. Sabel. *Work and Politics: the division of labor in industry*. (Cambridge: Cambridge University Press, 1982). Michael J. Piore and Charles F Sabel. *The Second Industrial Divide: possibilities for prosperity*. (New York: Basic Books, 1984).
[26] Charles F. Sabel. *Work and Politics: the division of labor in industry*. (Cambridge: Cambridge University Press, 1982).
[27] The difficulty is that the concept of flexible specialization has been so stretched that arguably anything could be counted as "flexible specialization" that is not traditional mass production but is adaptive to world markets involving flexible use of skill. Consequently the analytic and heuristic utility of the notion is diluted. The stretching occurs as the insights and concepts developed from the original cases are reformed to seek insight into new settings and to provide an optic on new questions. But in the process the notions are stretched to the breaking point. Our look at how and why that happens proceeds in three steps. Even this broader and, in our view, flawed, argument has made a contribution. But because we believe it now presses debate into needless diversions, the difficulties need to be emphasized in order to advance the common purpose of understanding the evolution of advanced industrial economies in their multiple forms.

First, how do we decide what is or is not an instance of "flexible specialization"? The concept of "flexible specialization" was initially associated with observations of companies and districts in Italy, and then Germany, of small- and middle-sized firms that embodied craft skills, were grouped in communities that provided support through a range of institutions and mechanisms, were given life by at least a minimum of trust and cooperation among the firms, and had direct access as individual companies or as a community of companies to the final markets for their products. Hence this community of "craft peers" could stand independently in a global economy. Those products, to rephrase the definition, are customized, made by skilled adaptable workers using flexible general purpose machinery. (Hirst and Zeitlin, "Flexible Specialization.")

But how do we decide what falls into and what does not fall into even such a restricted definition? Consider some cases: First, Cadence adapts scientific workstations (principally Sun Microsystems machines) to the task of designing semiconductors. The machines could be construed as general purpose, but their applications are very specific, and once tuned to those applications they could hardly be used efficiently to do mail processing which is another application of the same machines. Indeed, how flexible or how dedicated the machine is depends on how much money you pay to Cadence, which computer code and which form, to which a customer has access. What is the meaning of digital flexibility, and how does it correspond to notions of flexibility rooted in mechanical machines? The workers are certainly skilled, the source of technology is in Ph.D. training and is often highly mathematical in its conception. The core employees are skilled engineers or better. The entry level skill is rooted in formal training, not industry experience. Are Ph.D. and MA engineers too distant from the notion of skilled craftwork to fit our category? The firm was founded by arch-rival companies from Japan and the United States to provide a set of tools none could afford on their own, but they hardly form a community and notions of trust do not characterize the relationships of the founders. Indeed, Cadence works because collaboration without trust was possible. Cadence, a startup, has benefited from Silicon Valley's set of business institutions that foster and support new ventures. Though once a start up it is now has a turn-over of (). Where should we place Cadence?

Second, indeed, the semiconductor industry itself is composed in the United States of probably two hundred firms, but a handful of major firms such as Intel represent the major portion of the world market. Indeed, the direction and terms of competition of the industry is for the most part set by the large and dominant firms; the very terms of competition, and the exceptions to that, are likely to be on their way to becoming giants themselves. Those giants have a very firm division of conception and execution and the long runs associated with mass production. Intel, to take our title case, can build a billion dollar plant and amortize that plant in four months. That is very high volume. Phillips has recently proposed a new plant in England that should cost $1.5 billion. The rest of the firms are smaller players, significant because they represent technical and market threats to the established players. Indeed, most are efforts to parlay a particular skill--design or production --into a position of one of the enduring giants. From one vantage, the semiconductor industry is a world of flexible specialization. In our view, it is a whirlpool story of competition over design, standards, platforms, and networks with a core of giants and a periphery of would-be entrants and niche market players (For the debate see Martin Kenney's arguments with Anna Lee Saxenian in her book *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge, Mass: Harvard University Press, 1994)). The connections for supply and production are as powerful outside the region as within. Focusing on the loosely defined notions of "flexible specialization" or trying to pose Silicon Valley as a kind of high-tech Italy hides more from view than it reveals. Thus, importantly, how useful is it to group together into a single analytic category these smaller European craft-based firms and often very large knowledge firms rooted in the application of formal engineering or science?

Third, and the last of our examples, is the move of larger multi-nationals to adopt more flexible strategies. (Paul Hirst and Jonathan Zeitlin "Flexible Specialization: Theory and Evidence in the Analysis of Industrial Change" in J. Rogers Hollingsworth and Boyer (eds) *Contemporary Capitalism: The Embeddedness of Institutions*. (Cambridge: Cambridge University Press, 1997)) The process of corporate reform to produce systems that look "in fact, like one of the small firm districts…. with the difference that the service company rather than the municipality and employers associations provides the production units with whatever they cannot provide themselves." (Ibid) Let us set aside the question of whether particular cases are accurate representations, or typical representations, of corporate competitive reform. Should we see a corporate core operation, of any sort, as simply another version of community social institutions? Are operating units of companies that own those operating units, or of contractors that are dominated by their large clients, usefully conceived as cousins to community operations of peers? Indeed, rather than forming a piece of a single community with its suppliers, the large firm often plays off different "industrial districts", if you will, against each other. Loyalty, as in the case of Toyota's ties to Johnson Controls' seat division in Europe and North America, is just as often to a large firm, which in turn creates local operations. Choosing the small industrial region optic when characterizing the large firms may highlight commonalties, such as the use of skills, but hides and obscures the differences in power, strategy, community ties, and styles of operation that are distinctly different.

Ambiguity permits concept stretching. It is one matter to define the core elements of flexible specialization in order to point at empirical instances; it is another to specify them so clearly that we can decide which instances should be included in the group; and it is altogether a third, but equally important, matter to make sure the definition and the specification indicate clearly which instances should be left out. Until this is done it is hard to agree on what evidence emerges from the stories of given companies, industries, and regional groupings.

The study and discussion of flexible specialization pursues a variety of agendas, which in itself would seem to enrich the enterprise. However, the conflation of agendas often confuses the question of evidence and argument. Those fascinated by "flexible specialization" have several fascinating intellectual agendas about which they are very clear. One agenda is to demonstrate both that "each social world contains a number of possibilities" (Paul Hirst and Jonathan Zeitlin "Flexible Specialization: Theory and Evidence in the Analysis of Industrial Change" in J. Rogers Hollingsworth and Boyer (eds) *Contemporary Capitalism: The Embeddedness of Institutions*. (Cambridge: Cambridge University Press, 1997)) that often coexist in myriad blends and that the particular possibility that becomes dominant is the product of political and social development not some inherent efficiency or advantage. "Thus flexible specialization is concerned to rewrite history in order to show that the complexity of the past helps us to recognize that there are a variety of options in the present."(Ibid) The power of the normative enterprise of demonstrating the empirical plausibility of a world that echoes of independent skilled craftsman has drawn many to the heuristic and empirical tasks. Now we are sympathetic to this enterprise of discovering possibility and share many of these analytic concerns about the political/social formation of industrial systems. (John Zysman, "How Institutions Create Historically Rooted Trajectories of Growth"; and Zysman, "Nations, Institutions, and Technological Development" *International Journal of Technology Management*, Vol.12 Nos.3/4, Special Issue, 1996.) Historical work that shows that there appear to have been alternate roads of development in the past that were closed off by political or social choice is quite fascinating. Such historical case material cannot demonstrate the contra-factual argument that these principles of production could have constituted a fully blown industrial system nor that, for example, craft-based production could have sustained productivity development that was fast enough and broad enough to have truly given rise to an industrial society. Could a craft-based auto industry have emerged that drove productivity and provided transportation that was then within means of most of the population? If the sector is the wrong unit of analysis, since the auto as a dominant means of transport implies a particular approach to urban development and the policies to support it, then would that alternate industrial reality have been able to have provided the productivity increases across an economy that led to the American industrial miracle of the first half of the century? The contra factual enterprise by its nature can only provide hints of possibilities. Similarly, the discovery of aspects or elements of flexible specialization in Silicon Valley or Japan, if we are for a moment to accept the empirical characterizations, do constitute evidence that several forms of production may co-exist. They do not constitute evidence that the region or national system should be characterized as being flexibly specialized. It is plausible to contend that this "normative-empirical enterprise" is to be insulated from many forms of empirical challenge, since the purpose is to suggest possibilities and provide clues. But the converse must also be recognized; what serves as hints and clues of possibilities may not be rigorous enough or sturdy enough to constitute elements of data.

Similarly, "flexible specialization" is at once held out as an ideal type serving heuristic purposes but refusing empirical test, and as the basis of testable hypotheses about the character of industrial transformation. "Flexible specialization" is, thus, proposed as an ideal type whose appropriate measure is its "heuristic productivity" not its truth value. Hirst and Zeitlin write that "the appropriate criterion for the assessment of such ideal types is not their truth value but rather their heuristic productivity: how far does the conceptual framework of flexible specialization illuminate the observable processes of industrial change?" Again, as above, the result is that case material that is used to demonstrate the interest and utility of the ideal type becomes evidence of a particular kind of industrial transformation. The optic "flexible specialization" may identify interesting elements and insights in particular cases, but unless the ideal type is rigorously translated into deniable hypotheses--given precise operational research boundaries--those cases may not be useful for empirical tests. Hence hints and elements of flexible specialization suddenly become "empirical observations" or units of evidence that are accumulated as if they constituted a data set that could then provide evidence of a particular course of industrial development. Indeed, many of the cases labeled as evidence of "flexible specialization" are open to alternate interpretations and characterizations. When David Friedman, for example, finds a machine tool district in Japan he begins to characterize Japan as a misunderstood miracle, setting his community case against Chalmers Johnson's characterization of Japan. (Let us set aside the fact that Johnson's enormously provocative book consisted of an ideal type argument of the developmental state as introduction/conclusion and a history of MITI in the middle. That book, and the questions that ideal type compelled, would have to be judged enormously productive by the same criteria that the "flexible specialization" community would apply to itself.) Yet though fascinating and a useful reminder of the complexity of the Japanese development, Friedman's machine tool story itself steps around the powerful role of national policy in creating the Fujitsu Fanuc's Numerically Controlled Machine Tool controller as a standard that permitted the bevy of smaller firms and districts to specialize and thrive in the fashion Friedman describes. It avoids the role of national policy in creating a reserved market for Japanese producers both by excluding foreign competitors and by inducing demand among small- and middle-sized companies. If we are to consider his story as a piece of evidence in the empirical debate about the directions of production practice, we would not be willing on the basis of his evidence to characterize the Japanese machine tool industry as a whole as an instance of "flexible specialization" let alone the story of Japanese industrial development as a whole.

Let us characterize the difficulty. By asserting that the intellectual enterprise is largely heuristic and of a normative-empirical character, the argumentation surrounding "flexible specialization" shields itself from rigorous test. The problems emerge when the case material developed for these purposes is then redefined and becomes evidence in an empirical debate. Many of the cases and instances that emerge from this scholarship are fascinating in themselves as hints, often frustrating in our view by what they ignore or mischaracterize, but simply not acceptable as evidence for a general story.

Third, the use of the ideal type as a mechanism itself obscures possibilities. Just as the ideal types of "modern and traditional" locked Social Science into a debate about a single road from universal past to common present and thus hid the richer complexity of several paths from different pasts to distinct presents, the ideal type distinction between "mass production" and "flexible specialization" makes it harder to formulate the variety of trajectories of development. Barrington Moore's great and lasting achievement was to break apart that sterile debate and argue that the relation between landlord and peasant structured the processes of political and economic development so that they moved along separate paths to separate presents. Let us state the problem in a loose formalism. Using ideal types there is a tendency to argue that anything which has elements of Y and which is not X can be grouped as Y. Anything which is not "mass production" and has elements of what are seen as core components of "flexible specialization" should be taken into the set of "flexible specialization". Indeed, as we review many of the cases introduced in support of the "flexible specialization" insight, we conclude that while they contain elements of that ideal type or contain elements that are reminiscent of that type, the particular facts are often crammed into a mold of the "flexible specialization" side of a dichotomy. But perhaps, what is in front of us is neither Y nor X, but Z or B or C. Those other possibilities cannot, thus, be seen or identified. They are hidden by the methodology and multiple agendas of "flexible specialization". This is an ironic, and unfortunate, result for an enterprise that begins rooted in a commitment to display the variety and complexity of society and its past.

[28] See John Zysman, "How Institutions Create Historically Rooted Trajectories of Growth," in *Industrial and Corporate Change*, Vol. 3, No. 1, Oxford University Press, 1994

[29] This section is drawn from Globalization with Borders and more specifically its variation entitled "You Don't have to Be A Giant: How The Changing Terms of Competition in Global Markets are Creating New Possibilities For Danish Companies." Michael Borrus and John Zysman. February 1997

[30] By vertical control we mean both *vertical integration* from inputs through assembly to distribution as in the case of American auto producers, and the *'virtual' integration* of Asian enterprise group as when Japanese producers of consumer durables effectively dominate market relations with semi-independent suppliers through the Keiretsu group structure. See Masahiko Aoki, *The Japanese Firm as a System of Attributes: A Survey and Research Agenda* (Stanford, CA: Center for Economic Policy Research, Stanford University, 1993). *The Japanese Firm: the Sources of Competitive Strength* Masahiko Aoki and Ronald Dore eds. (New York: Oxford University Press, 1994); Masahiko Aoki, *Information, Incentives, and Bargaining in the Japanese Economy* (New York: Cambridge University Press, 1988); Michael L. Gerlach *Alliance Capitalism: The Social Organization of Japanese Business* (Berkeley: University of California Press, 1992).

After initial remarks below on the auto industry, the discussion of the evolution of competition in electronics and the emergence of Wintelism which follows is drawn from Michael Borrus, *Left for Dead: Asian Production Networks and the Revival of US Electronics.* (Berkeley: BRIE, 1997).

[32] The 'open-but-owned' rubric was first suggested in conversations with Robert Spinrad, Vice President of Technology Analysis and Development at Xerox.

[33] See François Bar and Michael Borrus, "Information Networks and Competitive Advantage: Issues for Government Policy and Corporate Strategy Development", *Final Report for the OECD,* (September 1989).

[34] There are numerous accounts of this period. Representative are James Chopsky and Ted Leonsis, *Blue Magic: The People, Power and Politics Behind the IBM Personal Computer* (New York: Facts on File, 1988) and Robert Cringely, *Accidental Empires: How the boys of Silicon Valley make their millions, battle foreign competition, and still can't get a date* (Reading, MA: Addison-Wesley, 1992).

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

[35] Michael Borrus and John Zysman, "Wintelism and the Changing Terms of Global Competition: Prototype of the Future" Working Paper 96B (Berkeley: Berkeley Roundtable on the International Economy, 1997).

[36] Michael Borrus and John Zysman, "Wintelism and the Changing Terms of Global Competition: Prototype of the Future" Working Paper 96B (Berkeley: Berkeley Roundtable on the International Economy, 1997).

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

[38] Michael Borrus, *Left for Dead: Asian Production Networks and the Revival of US Electronics*. *(Berkeley: BRIE, 1997).*

[39] Comments of William Miller, Professor Emeritus, Stanford University, and former President of SRI at the BRIE Working Meeting on Globalization, March 8, 1996.

[40] For an extensive discussion of this point and elaboration of such networked production structures, see Michael Borrus, Dieter Ernst, and Stephan Haggard, "Introduction" in *International Production Networks in Asia: Rivalry or Riches? (London: Routledge, 2000)*

[41] Such firm relationships to create a more intricate division of labor seem to take two forms. One division of labor will aim at creating economies of scale, hence grouping particular component or assembly activities of a similar character that are presently below optimal size. That first division of labor may result from the integration of a set of relatively homogeneous economies. When a region such as Europe began to generate a single market or when the United States and Canada reduced auto barriers, firms sought to capture newly possible economies of scale. What concerns us here is the second set of networks that emerge from linking diverse production locations.

[42] *Commodity Chains and Global Capitalism,* Gary Gereffi and Miguel Korzeniewicz, eds. (Westport, Conn: Greenwood Press, 1994)

[43] The material in this paragraph has been prepared with Sturgeon and is based on his dissertation and the relevant data sources cited there.
[44] According to Gilbert Amelio, the CEO of Apple Computer, the company's strategy is to outsourcing production to companies such as SCI in order to reduce some of Apple's manufacturing overhead and inventory carrying costs while positioning Apple to concentrate more intensively on marketing and design. *Electronic Buyers News*: April 8, 1996 Issue 1001, page 8.
[45] There are, of course, a range of questions we have not addressed above. These questions include: How do core firms maintain control over their CNPNs and, conversely, under what circumstances will network outsourcing undermine the capacity of the core firm to control the destiny of its own products? Under what circumstances is internal production still necessary? Sturgeon, Tim (1998) "The Rise of the Global Locality: Turnkey Production Networks in Electronics Manufacturing" University of California at Berkeley, forthcoming, 1998.
[46] Dieter Ernst, "From Partial to Systemic Globalization: International Production Networks in the Electronics Industry" BRIE Working Paper 98 (Berkeley: Berkeley Roundtable on the International Economy, 1997). Michael Borrus, Dieter Ernst, and Stephan Haggard, "Introduction" in *International Production Networks in Asia: Rivalry or Riches? (London: Routledge, 2000)*
[47] Thanks to Steve Weber for this example and insight.
[48] Lawrence Lessig. *The Future of Ideas: the fate of the commons in a connected world*. (New York: Random House, 2001).
[49] Indeed, unpacking the influence of the digital revolution on business altogether is not simple. Take the dramatic pronouncements that radically new business strategies facilitated by internet tools would permit market entrants to displace established players by "disintermediating them, that is by bypassing traditional links between companies and customers and creating direct links between company in the form of website and customer. This vision is representative of a series of notions that argued that the new information tools would change market dynamics throughout the advanced economies. Some analysts contended that the new tools for thought, and the business strategies they permit in turn, were altering the macro-economic dynamics of the economy, the character of business cycles and the pace of productivity.49 The simple fantasies – the end of the business cycle and the one stop cyber store -- never occurred. But business and business organization will not be the same.
[50] Stephen Cohen, Bradford DeLong and John Zysman. "Tools for Thought: What is New and Important about the 'E-conomy'". Working Paper 138 (Berkeley: Berkeley Roundtable on the International Economy, 2000).
[51] Stephen Cohen, Bradford DeLong and John Zysman. "Tools for Thought: What is New and Important about the 'E-conomy'". Working Paper 138 (Berkeley: Berkeley Roundtable on the International Economy, 2000).
[52] Because there is an integrated stream of innovation, that we refer to as the "tools for thought" and the information networks, the story of the present digital era is often told as an unfolding of technological possibilities from transistor to microprocessor to reconfigured digital communications networks. And certainly, some sense of the possibilities these technologies engender and the processes by which they were developed is essential to understanding the social and business possibilities.
[53] Isenberg, David, "Rise of the Stupid Network" (also available at http://www.hyperorg.com/misc/stupidnet.html).
[54] Carl Shapiro and Hal Varian, *Information Rules: a strategic guide to the network economy*. (Boston: Harvard Business School Press, 1997).
[55] Martin Kenney and Gary Fields, "Social Capital and Capital Gains of Virtual Bowling in Silicon Valley" in ***Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region. (Stanford: Stanford University Press, 2000).***
[56] The BRIE-IGCC Economy Project, *Tracking the Transformation*. (Washington, DC: Brookings Institute, 2001).
[57] Steve Weber and I are working on an essay on the Political Economy of the Digital Era. These remarks are drawn from those discussions.
[58] Steven Weber, *The Success of Open Source*. (Boston: Harvard Business School Press, 2002).
[59] Steven Weber, *The Success of Open Source*. (Boston: Harvard Business School Press, 2002).
[60] John Zysman.

[61] See John Zysman and Laura Tyson, "The Politics of Productivity: Developmental Strategy and Production Innovation in Japan" in *Politics and Productivity: The Real Story of How Japan Works,* Chalmers Johnson, Tyson, Zysman, eds. (Cambridge: Ballinger, 1989). (Cambridge: Ballinger, 1989).

[61] Wordweb Online Dictionary.

[62] The general argument may be found in: Michael Borrus and John Zysman, "Wintelism and the Changing Terms of Global Competition: Prototype of the Future" Working Paper 96B (Berkeley: Berkeley Roundtable on the International Economy, 1997). For a sector-specific look at these types of changes, consider: Michael Borrus and John Zysman, "From Failure to Fortune: European Electronics in the Changing World Economy" Working Paper #62 (Berkeley: Berkeley Roundtable on the International Economy, 1994).

[63] Michael Borrus and John Zysman, "Wintelism and the Changing Terms of Global Competition: Prototype of the Future" Working Paper 96B (Berkeley: Berkeley Roundtable on the International Economy, 1997).

[64] My thanks to Neils Christian Nielsen for a number of fundamental insights, of which this was one, that allowed me to begin to conceive this problem.

[65] Clayton Christensen, *The Innovator's Dilemma: when new technologies cause great firms to fail*. (Boston, Mass: Harvard Business School Press, 1997).

[66] Wordweb Online Dictionary

[67] Consider Tracking the Transformation: Full Cite