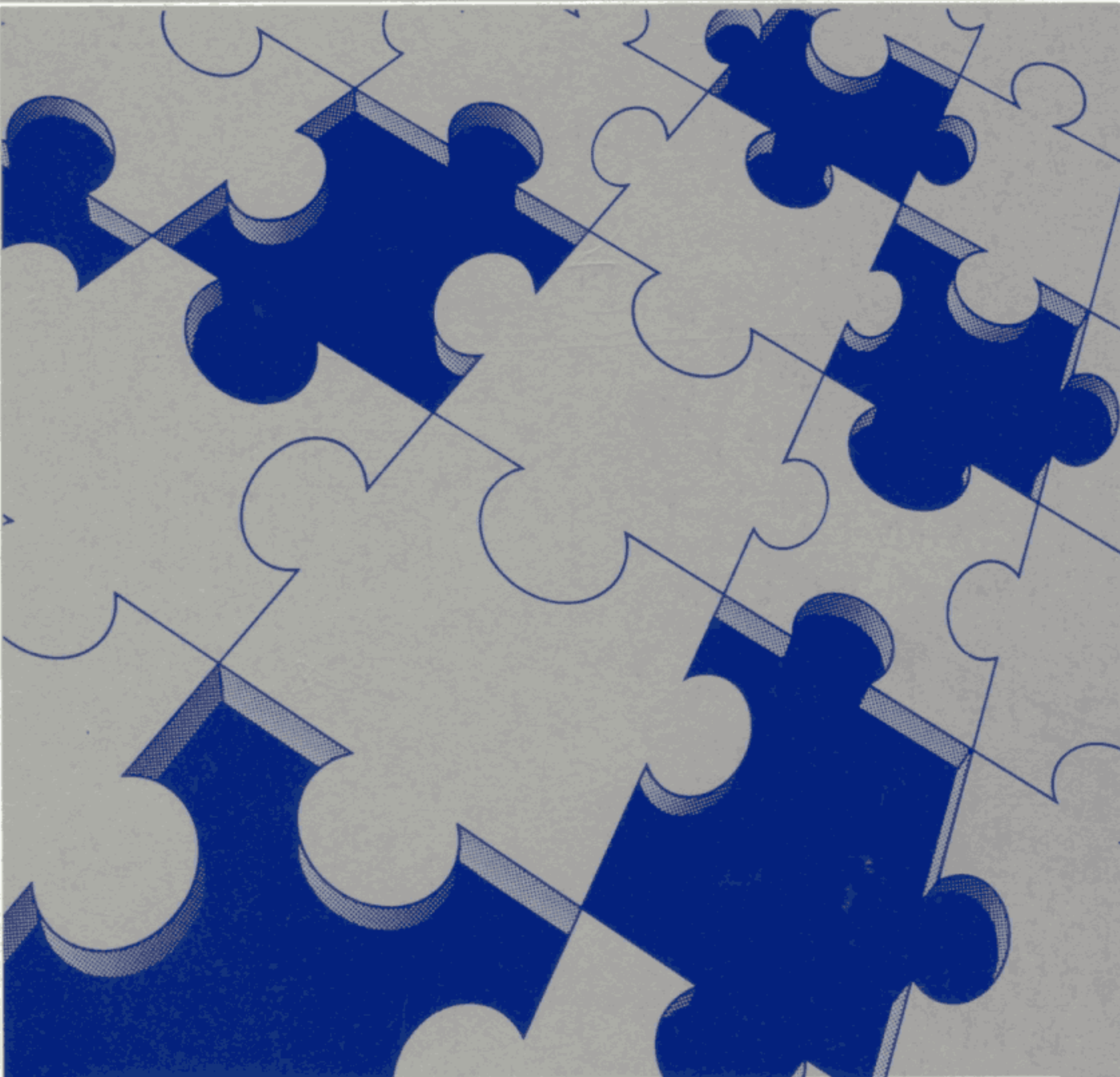


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THE NEW AGE OF CAPITALISM

Innovation-mediated production

Richard Florida and Martin Kenney

Capitalism is undergoing an epochal transformation from a mass-production system where the principal source of value was physical labour to a new era of innovation-mediated production where the principal component of value creation, productivity and economic growth is knowledge and intellectual capabilities. Capitalism in this new age of innovation-mediated production will require deep and fundamental changes in the organization of enterprise, regions, nations and international economic and political institutions. Survival in this new era will require the development of new organizational forms and systems, such as teams and new incentive systems, which decentralize decision making, mobilize intellectual capabilities, and harness the knowledge and intelligence of all members of the organization. This article outlines the fundamental trends emerging in this new age of capitalism and provides a detailed case-study of how one organization, a US-Japan joint venture steel mill in the USA, is organizing to meet the challenges of this new era. The conclusion outlines key lessons for the development of enterprise, regional and national strategies for both the technologically advanced countries and the developing world.

The factory itself is a living lab with bright capable people. The key is to use their brains. Those are your resources, your technicians, your labs, but they are out there on the operating floor. Constant improvement means constant change. You cannot get constant improvement, if you have the status quo. How do you get constant change? You get it by doing things you have never done before. Isn't that what they do in a lab? Try to figure out

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things they never did before. (Manager, I/N Tek, an advanced steel production facility, jointly owned and operated by Inland Steel and Nippon Steel.)¹

Before when we came to work in the morning, we used to check our minds at the factory gate. Now we are the source of innovation. (Worker in a US factory which is making the transition to innovation-mediated production.)²

A new age of capitalism is emerging out of the worldwide restructuring of the 1980s and 1990s, and it carries with it a whole new model of industrialization. This new system of capitalism is based on a synthesis of intellectual and physical labour—a melding of innovation and production. In fact, the main source of value and economic growth under this new system of capitalism is knowledge and intellectual capabilities. It thus represents a major advance over the previous Fordist system of mass-production capitalism where the principal source of value and productivity growth was physical labour. This epochal transformation is motivating, and will increasingly require, deep and fundamental changes in organization of enterprise, regions, nations and international economic and political institutions, and in the development of effective strategies for industrialization.

We refer to this new system as capitalism in an age of *innovation-mediated production*—a concept which refers to the integration of innovation and production, or physical and intellectual labour. Building on and generalizing from themes advanced in our book, *Beyond Mass Production*,³ we identify five major dimensions of this system of innovation-mediated production:

- a shift in the main source of value creation from physical skill or manual labour to intellectual capabilities or mental labour;
- the increasing importance of social or collective intelligence as opposed to individual knowledge and skill;
- an acceleration of the pace of technological innovation;
- the increasing importance of continuous improvement at the point of production;
- the blurring of the lines between the R&D laboratory and the factory.

Obviously, capitalism has been evolving along each of these dimensions for some time already. However, there is a qualitative new level to this evolution. Our concept of innovation-mediated production tries to capture the conscious and dynamic effort to re-integrate the activities of innovation and production and intellectual and physical labour which previously, especially in the anglophone countries, had been separated.

We pose our conceptualization in light of alternative two major conceptualizations of the future of capitalism. The first is the 'post-industrial' theory which argued that capitalism was moving from an industrial society to one based on white-collar information and service industries.⁴ While the post-industrial thesis makes the important point that the nature of capitalism is changing away from a system of value creation through physical production, it suffers from a series of conceptual limitations. First, there is no sustained analysis of what exactly constitutes a service.⁵ According to the post-industrialists, only sweaty, physical labour in traditional heavy industries qualifies as industrial activity. This is a very narrow definition. Is the woman who cooks a hamburger at McDonald's a service worker? She is performing an activity that physically transforms meat from an uncooked to a cooked state. There are some rather basic similarities between her work and that of a steelworker who transforms iron ore into steel. Is a software programmer a

service worker? The programmer produces a product that actually performs work—it sums numbers, runs machine tools etc. How different is this software worker from a machinist who through using his physical strength and knowledge of metal essentially instructs a machine tool in metal cuts?

Second, the post-industrial position rests on the belief that the advanced industrial economies would de-industrialize. Yet, the major industrial economies, including the USA, Japan and Europe, continue to have a considerable concentration of manufacturing activity, and derive huge sources of value-added from industrial activity. Predictions of de-industrialization⁶ have proved wrong, even for traditional heavy manufacturing regions such as the US midwest, as recent investments by foreign as well as domestic sources have revitalized manufacturing.⁷

Third, the shift to information-intensive activity itself is premised on industrial activity. A semiconductor fabrication facility or a biotechnology fermentation plant are industrial facilities, they are not post-industrial at all. All cost money to build, employ operators, and actually produce things. According to Michael Cusumano, software production in Japan can and does take place in factories which on many dimensions are comparable to Japanese automobile factories.⁸ Furthermore, innovative regions such as Silicon Valley, which are often viewed as the paradigmatic example of the shift to post-industrialism, continue to derive a great deal of wealth and value from industrial activity. In Silicon Valley, for example, manufacturing comprises 36% of total employment—a level which is considerably higher than that for the US as a whole and similar to that of the industrial Rustbelt.

Fourth, many core post-industrial technologies, such as software and computerized automation, are inextricably related to manufacturing and actual factory production. According to recent research, computer automation is most successful in environments where workers are integrated into the production process and where continuous learning can occur.⁹ In other words, effectiveness stems from an organizational context and concrete social relationships which optimize the use of new technology, not from technology that simply displaces workers. These social relationships are critical for implementing higher and higher levels of technology.¹⁰ And, as we demonstrate, to be truly effective in this new environment, the factory is more—not less—important. Indeed, the laboratory and factory must be linked in a continuum of innovation and production.¹¹ In short, the post-industrialists understand that intellectual activity will become ever more important, but make the mistake of assuming that industrial production will disappear.

The second view is the 'post-capitalist society' argument more recently articulated by the management theorist, Peter Drucker.¹² Drucker's position is that the rise of knowledge as a source of value is causing a shift in the nature of society from a capitalist foundation to a new economic base which goes beyond capitalism, and which thus represents a qualitative break with capitalist society as we know it. While we would agree with Drucker that knowledge is increasingly important as a source of value, we do not believe that the increasing role played by knowledge, intelligence and innovation in the economy represents a shift to a new, post-capitalist form of economic and social organization. In our view, capitalism has evolved in a dynamic way to harness and integrate knowledge and intellectual labour as sources of value within the boundaries of capitalist progress.¹³

This article outlines the fundamental trends emerging in capitalism in the age of innovation-mediated production, and provides a detailed case-study of how one organization, a US–Japan joint venture steel mill in the USA, is organizing to meet the challenges of this new era. In doing so, we hope to elucidate a number of key

trends and lessons which can inform enterprise, regional and national strategies in both the technologically advanced countries and the developing world.

Capitalism in an age of innovation-mediated production

The cornerstone of innovation-mediated production lies in the harnessing of workers' intelligence and knowledge in production. In fact, it is not physical labour, but human creative capabilities that generate value. This includes both physical and intellectual creativity. This conceptualization overcomes the traditional (and largely artificial) distinctions between innovation and factory production—a distinction that Harry Braverman and others immortalized as the separation of mental and manual labour.¹⁴ In contrast to this extreme view, we note that these two activities are more properly seen as different faces of the same general process of value creation. In short, value is created both on the factory floor and in the R&D laboratory.¹⁵

The new model of capitalism involves the blurring of the lines between production and innovation. The distinctions between the factory floor and the R&D laboratory are neither hard nor fast. Overlap between the two occurs frequently, and is increasingly promoted. Innovation becomes a continuous process. Experimentation and the recording of the results of manufacturing become a part of the production process itself. Workers, in conjunction with production and design engineers, are engaged in performing experiments and analysing results. Thus, roles and activities which were once thought of as involving only physical labour are transformed into information-rich arenas where knowledge and intelligence are applied.

Above all else, capitalism in the age of innovation-mediated production is premised on the mobilization of knowledge on a social or collective basis. This social knowledge includes both the abstract scientific and technical knowledge of R&D workers which is embodied in innovations and the knowledge of production workers which provides a crucial source of product and process improvements. This is a break with the conception of individual knowledge embodied in the 'lone inventor' or 'great scientist'. Under innovation-mediated production, knowledge is mobilized on a team basis. Thus, the team is used both to harness the knowledge of a group and to achieve functional integration of tasks. Team-based work organization integrates formerly discrete tasks, eg R&D and factory production, making the production process more social than it was previously, and re-integrating aspects of the division of labour which were individualized under the previous Taylorist and Fordist systems.¹⁶ In doing so, the organizational forms of the new production system mobilize and harness the collective intelligence of workers as a source of continuous improvement.

Such tendencies are propelled by related and fundamental changes in the nature of technology, the innovation process and capitalist competition. Tessa Morris-Suzuki has described this as 'perpetual innovation', a concept which she uses to refer to an economy in which value is created through a process of rapid, continuous and accelerating technological change based on a shift to new information-intensive technologies and industries.¹⁷ This system allows capitalist firms not only to create new products, but also to diversify rapidly and customize existing products, opening up new markets and tapping into new market spaces at the margins of existing markets. This contrasts with the more standardized outputs of the Fordist factory. This development is in turn driven by the increasingly severe

competition in all market segments. This rapid market churning means that products rapidly become obsolete, driving an even greater acceleration of new product introductions.

Capitalism in an age of innovation-mediated production emphasizes both the introduction of new technologies, and perhaps more important, what Fumio Kodama has referred to as the 'fusion' of technologies and continuous incremental improvement of process technologies.¹⁸ Under this system, engineers and designers develop new technologies and big innovations, while production workers and factory-level engineers refine and improve existing technologies. In this way, incremental innovations provide an important underpinning for major advances. Continuous process improvement enables factories and production sites rapidly to bring new models into production. Survival requires the dual capabilities of rapid introduction and rapid improvement of innovations and production systems.

Melding of innovation and production

The shift to innovation-mediated production is destroying the boundaries which once separated innovation and production—the laboratory and the factory—bringing forward whole new modes of enterprise organization. Heightened competition and the accelerated pace of technological innovation result in a more or less continuous stream of commodities which make previous generations appear obsolete, create new demand, and generate new streams of value, profit and accumulation. The short product life-cycles and rapid performance increases associated with new technologies make innovation itself an increasingly important source of value. In this new environment, economic success and competitiveness are tied to a firm's ability constantly to improve products and processes, to revamp the production process itself, and rapidly to deploy new products and technologies.

Under the previous Fordist system, the R&D laboratory was separated from the factory and its role was conceived as creating innovations that would be implemented by others. College-trained researchers and engineers were considered the white-collar or managerial class. There was a fundamental distinction between them, technicians and factory workers. The factory was not viewed as a site for creative work, but rather where 'second-rate' engineers were sent. The separation of conception and execution outlined by Harry Braverman was accepted as an axiom.¹⁹ According to the myth of the modern robotic factory, workers would be reduced to machine minders and button pushers and ultimately removed from the production process entirely. Brains, like power, were centralized up the corporate ladder.

Under innovation-mediated production, the extraction of intellectual (and manual) labour clearly becomes a more social, inter-subjective, and collective process than under previous capitalist epochs. Knowledge and intellectual labour are mobilized on a collective basis. As mentioned above, the team is the basic organizational mechanism used to harness the collective intelligence of researchers, engineers and factory workers and turn it into commodities. The self-managing work team facilitates the functional integration of tasks, and in turn, overcomes the fine-grained functionally specialized division of labour of Fordism.²⁰ It is the mechanism through which workers are mobilized to solve production

problems and to become agents of innovation, as workers use their collective intelligence and knowledge to devise new and more efficient production strategies.

In innovation-mediated production, the intellectual capabilities of a variety of different types of workers are integrated and explicitly harnessed to turn knowledge into commodities. This overcomes the managerial stratification schemes developed in the USA and Europe, and thereby facilitates efficient production, resulting in a 'fusion' of researchers who create innovations, engineers who develop them and turn them into commercial products, and shopfloor workers who produce them. Overlapping team membership allows R&D workers to work alongside product development engineers and even factory workers, blurring the boundaries among them. This creates an interplay and synthesis of various types of knowledge and intellectual labour in an explicitly social context. Such integration of functions is required so that all the relevant actors can interact, exchange thoughts and create new ideas, as a unified 'social brain', and then translate and embody those ideas in new products and production processes.

Of course, production really was social all along. More than a century ago, Marx highlighted the social and inter-subjective nature of capitalist production.²¹ At the core of Marx's argument was the proposition that the advance of the productive forces requires greater socialization of production over time—thus the movement from individual artisanal production, to simple manufacture, to machine-based manufacturing or what Marx termed 'machinofacture'.²² Furthermore, when labour sociologists and anthropologists visited the shopfloor, they frequently reported back on the social aspects—such as workers talking together, sharing tasks, or solving problems without telling management.²³ However, these social aspects were typically viewed as aberrations that occurred outside the bounds of what industrial engineers and managers codified in job descriptions. Under Fordism, even though tasks were organized on an individual basis, the division of labour in the Fordist factory reconstructed these individual actions in a social production process. The social could also be seen in the creation of a huge class of industrial workers, and the growth of the new industrial unions, which came to represent these workers. Innovation-mediated production explicitly recognizes the social nature of the production process as integral to innovation, value creation and economic growth.

Blurring of industrial boundaries

These changes at the point of production are being combined with important changes in corporate organization and in the division of labour between and among firms. This is evident in high-technology industries where formerly separate sectors such as semiconductors, computers, software and consumer electronics are intermingling. It is also evident in the linkage between traditional and high-technology industries as automobile and steel production undergo new waves of creative destruction and are themselves transformed into high-technology industries. Increasingly, automobile and steel companies must produce software, integrated circuits, programmable logic controllers, advanced robotics and machine tools and the artificial intelligence and software programs which run those various machines, tools and pieces of equipment. These companies are developing their own software capabilities, spinning out software subsidiaries, and investing in high-technology start-ups as they endeavour to compete in the new age of technology-intensive, digitally based manufacturing.

The boundaries of the traditional capitalist firm are being redefined. The current debate over the changing organizational morphology of the capitalist enterprise misses the crucial aspects of this reorganization. Many have noted that a cornerstone of advanced production systems is the rise of complex interconnected networks of firms organized in various types of complexes or 'industrial districts'.²⁴ This debate typically contrasts two ideal-types: the vertically integrated firm of either the USA or Japan and cooperative small firm networks.

The real issue, however, is not where the lines of the enterprise are drawn, but how organizational forms produce and harness value. Corporate networks, such as the just-in-time hub-spoke systems pioneered by Japanese enterprises and which are now diffusing throughout the industrial world, are not simply new mechanisms for efficient parts supply and procurement. They function as yet another organizational mechanism for mobilizing knowledge and intellectual labour on a collective, social basis. The networks provide a powerful dynamic for innovation. Each firm in the network feels economic and social pressure to improve. Furthermore, as Ken-ichi Imai points out, since these activities are separate and each firm is judged by its profitability, and as such, is constantly meeting the test of market competition.²⁵ Each firm thus receives a rich array of information from the market that it might never receive if its activities were simply a component of an integrated firm. Decentralization of R&D functions is advantageous, as all firms in the network come under pressure to innovate to improve efficiency, reduce costs, and introduce more advanced products. Knowledge is thus mobilized and accumulates within the network. As the R&D and technological knowledge embodied in each firm advances, the network accumulates greater innovative capability and each firm becomes a more valuable member of the network. Such upgrading is in the interest of the end-user, and they encourage the process through the extension of technical and other assistance. Thus, the entire network evolves in a way that is similar to constant improvement on the factory floor. The network becomes another format for continuous innovation and improvement. Thus, the network is itself an organizational adaptation to innovation-mediated production.

The factory as laboratory

Perhaps the most fundamental element of capitalism in an age of innovation-mediated production is the transformation of the factory itself. The modern factory is becoming more like a laboratory—the place where new ideas and concepts are generated, tested and implemented. The factory can no longer be merely a place of dirty floors and smoking machines, grease, muscle and sweat, but is increasingly an environment of brainpower and technological innovation. The operation of the new factory requires a massive mobilization of workers' intelligence, not just their physical capabilities and skill.

The factory as laboratory represents an epochal transition in the nature of both manufacturing industry and industrial capitalism. Ever since the transition from feudalism to capitalism, the basic source of productivity, value and economic growth has been physical labour and manual skill. In the new factory, knowledge, intelligence and intellectual labour replace physical labour as the fundamental source of value and profit. This is not simply the knowledge and intellectual capabilities of R&D scientists and engineers, but the knowledge and capabilities of all workers—including those on the shopfloor. In this new environment, workers at

the point of production use their knowledge and intellectual capabilities directly to improve products and processes collectively and continuously.

Seeing the factory as a laboratory is inherent to developing a broader understanding of the nature of innovation. Under the old Taylor–Ford model of mass production industry, new products and processes would be invented by one, or at most, a few great minds working in a controlled laboratory setting. It was typically rather difficult to scale up these new ideas for a real production process. It is one thing to invent a new process; it is another to make it work in a real factory setting. In the factory as laboratory, there is no longer a strict and rigid separation between R&D, product development, design engineering, pilot production, and manufacturing. The lines between the factory and the laboratory blur as the factory itself becomes the centre for both production and innovation. This new factory moves beyond the separation of the artificially controlled environment of the R&D laboratory and the complicated real world of the factory, and allows manufacturing processes to be designed, implemented and continuously improved in a realistic setting.

The factory as laboratory is a centre for constant innovation and improvement. Robert Cole captured one dimension of the new factory when he argued that the Japanese factory is becoming a 'school' in which learning constantly takes place.²⁶ But learning alone is not sufficient; it is the application of that learning that is crucial, and that occurs through innovating. The new factory is a living technological system—one that is constantly improving itself.

The factory is increasingly taking on the physical characteristics of the laboratory as well. A laboratory is a controlled environment designed to exclude entropy or transient events that can interrupt experiments. The new factory is similar. Dirty, untidy plants are harbours for transient events which disrupt production. The new factory requires a clean-room environment as free as is possible of dust, particles and other impurities which may affect the production process. Yamazaki Mazak, for example, assembles certain parts of its machine tools in a class 10 000 clean room. Keeping the factory clean and particle-free decreases the probability that foreign materials will enter and disrupt the production process. In fact, production increasingly takes place in an environment in which direct human intervention is minimized. The future is one of humans monitoring, controlling and programming, but not directly touching the work-in-process; this is accomplished by robotic and other automated tools. This is most visible in new semiconductor and consumer electronics plants where robots, monitored, controlled and sometimes even programmed by shopfloor workers, are doing the physical aspects of the work. This is also occurring in continuous-process steel mills and on automotive painting lines.

The factory itself is changing from a centre of physical labour, grease, muscle and sweat to a locus of continuous innovation. Indeed, the factory itself is becoming a laboratory setting for both product and process innovation. Organizing the factory as laboratory allows new products to move from the controlled setting of the R&D laboratory to the factory rapidly and with a minimum of problems, and allows processes to be worked out in a realistic setting. In this new environment, operators and technicians actively participate by using their knowledge to improve products and process—to stabilize production. The entire process is closely monitored as information is constantly collected, fed back, and used to improve the process.

In some new factories, laboratory-like spaces are available for workers. These typically include sophisticated laboratory-like equipment—computerized measur-

ing equipment, advanced monitoring devices and test equipment. Modern steel mills, for example, come equipped with technologically sophisticated ladle metallurgy facilities where mill operators are able to adjust scientifically the basic chemistry of molten steel while it is being made. Workers use these laboratory-like spaces together with R&D scientists and engineers to analyse, understand, fine-tune, and improve products and production processes.

The factory as laboratory demands new organizational structures, new incentives and new mechanisms to elicit workers' cooperation and to mobilize and harness their ideas. This goes far beyond the old feel-good techniques of labour-management cooperation, quality-of-work life, labour-management committees, and 1980s-style quality circles. This is a deep organizational refashioning which is absolutely required to make the factory a centre for innovation and the constant application of intelligence.

The factory as laboratory also requires a new type of worker. This new environment places a premium on the ability to manipulate abstract constructs as opposed to the physical or craft-based skills of more traditional manufacturing. Workers are required to operate computerized machines, understand and program computers, and use their minds as well as their physical capabilities. These new workers require skill levels which are equivalent to the electrical engineers of two decades ago. The new worker must be trained and managed more like a researcher or engineer rather than as a traditional factory worker.

Inside the factory as laboratory: a case-study

The new system of innovation-mediated production is not confined to so-called high-technology industries. These trends are far more pervasive and have the potential to affect every factory. This section examines the developments at I/N Tek, a joint venture between Inland Steel and Nippon Steel, Japan's largest steel company. This case-study provides important insights into how an operating production facility is currently implementing the factory as laboratory concept. The I/N Tek facility is part of a \$1 billion plus joint venture between the two companies which includes I/N Kote, a \$500 million electro-galvanizing line, as well as I/N Tek itself, a \$430 million new cold-rolling steel plant.²⁷

The I/N Tek facility is located just outside South Bend Indiana in the heart of the so-called US Rustbelt. It is a continuous cold-rolling mill which combines a series of formerly discrete batch processes into a continuous process. This is only the second continuous cold-rolling mill constructed in the world, the other being Nippon Steel's continuous cold-rolling mill at its Hirohata Works in Japan on which I/N Tek was modelled.

The factory itself is striking. Housed in a modernistic white building, inside there are high-tech machines, metallic guard rails and walkways, and a brightly polished concrete floor. Gleaming sheets of steel move extremely rapidly through the machinery, like sheets of paper through a paper mill. At the centre of the process stands a large glass-enclosed booth housing computers, digital displays and electronic gauges and controls. Workers, managers and engineers all in the same uniforms watch over the process but do not actually handle the steel. Operators working with engineers and supervisors monitor, modify and program the computers that guide the steel-making process. These workers, engineers and supervisors are constantly discussing new ways to improve the process and make it more efficient. Strikingly, there are no time-clocks or time-cards in this factory;

everyone here is paid on a monthly salary. The mill produces cold-roll steel in less than an hour from start to finish—a process that formerly took as long as 12 days.

The cold rolling of steel has traditionally been a finishing stage which comes after steel has been cast into slabs in an integrated mill and then heated and rolled into coils of sheet steel in a hot-rolling mill. However, this hot-rolled steel does not possess the high-quality properties required for high-value steel products such as automobile steel, refrigerator doors, or office desks. Cold-rolling provides these properties, and cold-rolled steel is used in a host of products and applications from filing cabinets and home appliances to automotive body parts. I/N Tek's automated, continuous process produces clean, flat steel coils with little variation in thickness and with precise and consistent metallurgical properties—that is, they do not vary from coil to coil. Cold-rolled steel is also used in steel galvanizing and finishing lines which coat the steel for even higher-quality, higher-value applications such as rust-resistant automotive body parts.

In both the USA and Europe, the cold rolling of steel has traditionally been a batch process. This involves five separate, discrete processes—descaling, pickling, tandem rolling, annealing and tempering—where steel is processed and transferred one step at a time from one process to another. First, the steel would go to a descaling process that essentially cracks the rust and oxidation on the surface, then onwards to be soaked in a chemical solution of hydrochloric acid, referred to as pickling, to chemically remove the surface oxides from the hot-rolling process. The next step was for the cleaned steel coils to be squeezed to the desired thickness. They would then proceed to final cutting and preparation. At Inland Steel, the work-cycle was typically two weeks or more, and the product quality was low. Costs were high due to the many batch steps and inventory costs.

I/N Tek has adopted advanced technology to turn this into a highly automated continuous operation which takes less than an hour to complete. Nippon Steel linked all the formerly discrete steps into a single continuous operation that resembles the production of rolls of paper in a paper mill. While this may appear to be a miraculous breakthrough in steel-making technology, it was accomplished by combining a series of small, incremental process innovations in an evolutionary fashion. An I/N Tek manager noted:

They started in one place and they put the pickle lines and tandem mill together. In another place, they put the tandem mill and the anneal together. In another place they put the anneal and finishing together. Different combinations. They saw what worked and finally they put it all together.

This innovative process was not achieved in an isolated R&D laboratory far from the factory. It was accomplished by harnessing the innovative capabilities of shopfloor workers in the factory. The workers were actively engaged in developing process innovations and implementing them in practice. These workers undertook activities that under Fordism would have been the sole province of white-collar engineers. Regular steel operators were enlisted in the continuous experimentation to develop continuous improvements and methods of linking the separate steps in the production process. The company mobilized both factory workers and R&D workers to combine the various batch processes. Initially, the entry and descaling processes were linked into one step. Then the pickling and tandem-rolling processes were put together, and so on down the line. With the help of computer specialists computer controls were added. The end-result was a continuous pro-

duction process. Now the I/N Tek plant is connecting the cold-rolling process to the two new galvanizing lines at a contiguous sister facility, I/N Kote.

The role and importance of regular shopfloor workers is central to the entire process—they work the machines and program the computers which control the production process. The factory has been transformed into an arena in which workers' intelligence is the source of continuous manufacturing process improvements that are crucial for corporate success. Workers are directly responsible for the quality and can stop the line to remedy quality problems. At I/N Tek, there are screens and computer monitors on the shopfloor where workers watch the product and adjust the process. This contrasts sharply with traditional industrial practice where such activities were the province of white-collar managers and engineers. The operations manager at I/N Tek describes the way traditional steel operations worked:

Many times people were afraid to stop the operations if they had a quality problem because they would have to answer many questions as to why they did that. There was always the fear that if they had not made the decision properly that they would be in trouble and there was always fear of reprisal.

The factory as laboratory requires new, more collaborative relationships between management and labour. At I/N Tek, management and labour worked together to develop a new labour agreement that would facilitate the new model of work and production organization. The agreement allows for just five job classifications for workers. This stands in marked contrast to the hundreds of distinct job classifications in a traditional steel mill. High rates of pay encourage and motivate innovation and productivity. The average base pay for skilled workers was roughly \$32 000 annually in 1990, and workers have the opportunity to earn considerable bonuses and overtime pay which can be as much as an additional 45–50% of their regular salary. The plant uses a pay-for knowledge system to encourage workers to learn additional skills and become multi-functional. Self-managing work teams are a central component of the new agreement between labour and management. The actual labour contract includes the following passage.

Autonomous Work Teams form the building block of the organization. The Teams will be self-directed, relying on group consensus to arrive at decisions regarding the manner in which tasks are assigned and responsibilities are to be carried out. These Teams will share responsibility with management for assisting and training team members in achieving the skills necessary for the operation of the Mill, understanding of the processes and performance as Team members. This will include responsibility for: planning the work, scheduling the work, coordinating activities within and outside of the Team, producing a quality product, producing to schedule, performing within budget constraints, making job assignments within the Team, maintaining equipment, controlling inventories, controlling scrap, ensuring compliance with safety and health standards and improvement in such standards, obtaining tools and supplies, keeping records, training, determining working environment and other quality of work life matters. Team members may counsel one another with respect to absenteeism and other problems affecting their work.

There was some debate over where to locate this new steel facility. Both Inland Steel and Nippon Steel initially considered whether to locate the facility on Inland's huge existing Indiana Harbour steel complex or alternatively move to a non-union region, eg the Sunbelt, to implement the new work and production system. While some top management officials made the case against the union, others argued that unionization would provide the labour force stability required for state-of-the-art continuous cold-rolling. It was ultimately decided to put the plant on a

greenfield location close to its existing integrated production facility and close to its customers, but which could provide a blank slate environment free from the ingrained organization, culture and behaviour associated with the old Inland Steel complex. In the words of one manager:

You have an engineering system here that basically has taken all of the labor out of it. If you can convert the labor structure such that it is a win-win when you win, and lose-lose when you lose, you have everything aligned, congruence in your mission, and how you measure success. We think we have a labor cost advantage. You talk to people and they will say: 'You pay too much for your people'. In the long run, I don't think we are paying too much for our people. We expect to get much more value out of them. They become an asset and become the reason you are in business longer.

The I/N Tek plant cannot use the old industrial worker or their managers—new types of worker are necessary. Recruitment and training of employees was and is a crucial activity. As in the laboratory, the new factory requires an educated, committed, enthusiastic worker. The company used aptitude, technical and psychological screening tests, technical tests, workplace simulations and detailed personal interviews to choose carefully its workforce. Workers who made it through the tests were sent to an assessment centre where workplace simulations were used to evaluate interpersonal characteristics, analytical abilities and ability to work in a group context. Roughly 10% of the 1250 workers who took the tests were selected to work in the plant. The manager of human resources who was involved in this process noted:

We were looking for people who had an ability to analyze for themselves, diagnose problems, develop their solutions, to take action, be self-starter, go beyond the norm, not need to be directed, not want to be directed. We wanted people who are capable of working with a group of people who are very much like them, so they would not be antagonistic toward one another in such an environment.

Workers were then sent to Japan for two to six weeks of training. Roughly two dozen Japanese trainers returned with them to the USA to provide additional instruction. Training and socialization have continued on the job and are aimed at constantly improving the capabilities of the workforce. A manager noted: 'Training is like R&D. It is your commitment to improve your people'. In practical language, this manager has captured the essence of innovation-mediated production—the continuous development of human creative capabilities as a source of innovation and value.

Implications and future prospects

The dawn of a new era is upon us—capitalism will never be the same. The I/N Tek plant we have examined here provides a powerful example of the new industrial revolution that is under way in the advanced capitalist world. As we have seen, under capitalism in an age of innovation-mediated production, knowledge and intellectual labour replace physical labour as the fundamental source of value, capital accumulation and profit. Indeed, advanced industrial economies are changing from a system premised on the mere extraction of physical labour to one based on continuous knowledge mobilization and innovation. This is not simply the knowledge and intellectual capabilities of R&D researchers and engineers, but the knowledge and capabilities of all workers—including regular factory workers. Workers' knowledge is now a fundamental and explicit element of production and

of continuous innovation—a source of direct value-creation and productivity improvement. Enterprises, regions and nations that cannot adapt to these fundamental changes will be at a disadvantage and may indeed find themselves increasingly at risk.

Contrary to the hopes of many business and political leaders in Europe and the USA, there is no avoiding this future. Attempts to bolster the old order through measures such as trade protectionism or by subsidizing failing firms and industries, cannot work. One of the harshest, yet most progressive, aspects of capitalism is the Darwinian nature of the competitive process—it will not allow inefficient enterprises, regions or nations to hide behind government-constructed barriers for long. Enterprises must adapt if they want to survive. There will be less and less space for firms that continue which remain locked into outmoded Fordist management practices—which continue to view workers as mere 'hands' to be exploited or worked at as fast a pace as possible. Attempts by unions to retaliate against this new system by opposing the formation of teams or other forms of work organization which seek to harness workers' ideas will only be counterproductive.

Government too will have to change to meet the demands of capitalism in an age of innovation-mediated production—both in terms of its internal organizational structure and its public policy activities. Government policy, which has developed over the past century to meet the needs of various constituencies of the old Fordist order, must change dramatically to reflect the underlying functional requirements of this new capitalism. Motivated by the underlying dynamic of Fordist capitalism, government policy evolved as a system of specific interventions in functionally specialized policy domains—banking policy, trade policy, economic policy, labour policy, transportation policy, housing policy, development policy, welfare policy etc. Under innovation-mediated production, policy will be increasingly called on to cut across boundaries and integrate these various functions. Under innovation-mediated production, government policy will increasingly have to move away from specific interventions to a new approach which focuses on building the broad infrastructure of technological, manufacturing, physical and human capabilities required for the new system to function and evolve further.

The organizational structure of government will also have to change to meet the needs of the new system. The existing organization of government itself reflects the hierarchical and functionally specialized structure of Fordism. This structure will have to change to reflect the underlying functional requirements of innovation-mediated production—this is in fact what is already motivating the movement in the USA and elsewhere to 're-invent government'.²⁸ As we have seen, innovation-mediated production harnesses knowledge and a fuller range of human capabilities than did Fordism. The harnessing of human capabilities must be the central organizing principle of government and public policy reorganization as well. This will require increasing functional integration of government through the use of teams, decentralization of functional responsibilities to operators and front-line workers, greater empowerment of government workers and work teams, and perhaps even a scaling back of government activities and/or restructuring of government activities to lower levels of the hierarchy such as regional government. Although it may appear exceptionally remote or even impossible from the current vantage point, government itself will in time come to reflect the core principle of continuous knowledge mobilization under innovation-mediated production.

Capitalism in the age of innovation-mediated production has serious implications for the developing countries. There is likely to be a continued, differen-

tiated path of development for the Third World. Countries in South America and other regions which are closely linked to the outmoded Fordist model are likely to decline if they do not change, while nations in the Pacific Rim, from the 'four tigers' of Korea, Taiwan, Singapore and Hong Kong to newly industrializing and developing nations such as Malaysia, Indonesia and China, will continue to experience growth as they are integrated into the diffusion of innovation-mediated production outwards from Japan. Furthermore, the emergence of innovation-mediated production implies that the old Fordist system of development practised by Western European and North American multinationals is no longer an appropriate model on which to base future development strategies. Attempts to lure low-cost Fordist branch plants will become increasingly counterproductive as the nature of capitalist production shifts to increasingly knowledge-intensive production. Third World nations and firms must adapt to the new system of innovation-mediated production and develop strategies to develop and harness the knowledge and innovative capabilities of their workforces. Sadly, this may be impossible in the typical hierarchical Third World company. Yet, ironically, this new model of development does not require huge investments in technology. Even if a country or firm has limited resources to invest in formal R&D, shopfloor workers comprise a crucial source of innovation and improvement. Thus, every nation and every firm have assets for innovation, which can be unleashed if their human resources are cultivated and managed properly. The developing nations must seek to combine foreign direct investment, with the development of both an indigenous manufacturing infrastructure of supplier firms, and strategies to develop the human infrastructure of workers who can actively contribute their intelligence. A key factor in future development strategy will be the ability of these nations to adopt key aspects of innovation-mediated production and develop both the manufacturing and human infrastructures required to support it.

Most of all, this new system of innovation-mediated production will require a new global organizational and institutional framework to orient and structure trade, investment, environmental and security considerations. The structural weaknesses of the current system, which was designed to meet the needs of the previous Fordist model of capitalism, are not only evident—they are increasingly an obstacle to the further evolution of the new system of innovation-mediated production. The development of a new institutional framework will not happen quickly, as it took three to four decades to fashion a workable set of national and global institutions to support stable growth under the previous system of Fordist capitalism. While the contours of innovation-mediated production are now coming into view, fashioning an integrative set of institutions to support this new system of capitalism remains hard even to envision, and is likely to require decades of experimentation, bargaining and negotiation to set in place.

Notes and references

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 19. Harry Braverman, *Labor and Monopoly Capital* (New York, Monthly Review Press, 1974).
 20. This section builds upon concepts initially advanced in Richard Florida, 'The new industrial revolution', *Futures*, 23(5), July–August 1991, pages 559–576.
 21. See Karl Marx, *Grundrisse* (New York, Vintage Books, 1973, original 1858, translated by Martin Nicolaus).
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 27. This case-study is drawn from extensive field research consisting of multiple site visits, factory studies and dozens of interviews with key personnel related to the I/N Tek plant in both the USA and Japan conducted by Richard Florida over a three-year period.
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