The Economist Intelligence Unit

A report from the Economist Intelligence Unit

Networked manufacturing:

The digital future

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Contents

About this research

Networked manufacturing: The digital future is an Economist Intelligence Unit report that discusses the promise of networked manufacturing; conditions that may enable a successful shift to networked manufacturing; and the potential economic impact of digital production. The findings of this briefing paper are based on desk research and interviews with a range of experts. The Economist Intelligence Unit would like to thank the following experts (listed alphabetically) who participated in the interview programme:

- Wilhelm Bauer, acting director, Fraunhofer Institute for Industrial Engineering IAO, Germany
- Rudolf van der Berg, information economist / policy analyst, Organisation for Economic Co-operation and Development, France
- Kenneth DeWoskin, senior adviser, Deloitte China, and director, China Research and Insight Centre, Deloitte, China
- Michael Jackson, special advisor to the secretary for manufacturing, Office of the Secretary, US Department of Commerce, US
- Henning Kagermann, president, National Academy of Science and Engineering (acatech), Germany
- Tobias Krause, researcher, Fraunhofer Institute for Industrial Engineering IAO, Germany
- James Manyika, director, McKinsey Global Institute, US
- Michael Molnar, director, Advanced Manufacturing National Programme Office, National Institute of Standards and Technology, US
- Christian Reimsbach-Kounatze, information economist / policy analyst, Organisation for Economic Co-operation and Development, France
- Jagjit Singh Srai, head, Centre for International Manufacturing, Institute for Manufacturing, University of Cambridge, UK
- Dieter Spath, president, Wittenstein, Germany
- Ricky Tung, manufacturing managing partner, Deloitte China, China
- Howard Wial, director, Centre for Urban Economic Development, University of Illinois at Chicago, US

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Executive summary

Developed manufacturing nations such as the US, Japan and Germany are under pressure to enhance their manufacturing capabilities. These countries are already falling behind China in terms of competitiveness; in the next five years, they are expected to fall even further behind. At the same time, enhanced manufacturing capabilities are increasingly important for developing nations, especially China, which risk losing their competitive advantage as labour costs continue rising in the medium and long term.

For developed and developing manufacturing economies alike, networked manufacturing—which uses data flows to drive better communication, co-ordination, and control in and around manufacturing—has the potential to secure competitiveness. Making use of such information flows promises greater production flexibility and a host of other benefits.

This paper is based on desk research and in-depth interviews with experts including manufacturing professionals, policy makers, and academics. It discusses the promise of networked manufacturing, the conditions that may enable a successful shift to networked manufacturing, and the potential economic impact of digital production. Here are the key findings of the research:

1. Digital production offers manufacturers vital flexibility.
Networked production systems that harness data flows to control and optimise production may enable manufacturing of small volumes and customised production. In turn, this has the potential to offer manufacturing companies greater flexibility to respond to the market. At the same time, networked production promises greater efficiencies.

2. The shift towards networked production is just beginning.
According to Deloitte China research, 77% of China's industrial machinery makers agree that next-generation manufacturing capability is important. Yet it is still early days for networked manufacturing. So far, there is little agreement among manufacturers and policy makers on how to shift towards digital production, and few companies have taken steps to adopt digital production.

3. Pre-requisites for a shift to networked production include several policy drivers.
Among the conditions that enable a successful shift to networked manufacturing are freedom of trade and freedom of information across borders. Robust communications networks, technical standards and data security are further pre-requisites. Not least, workforce skills are a key

requirement. Policy makers can help to foster an environment conducive to digital manufacturing by focussing on these pre-requisites.

4. Governments alone cannot drive the shift to networked manufacturing.
Whilst governments have a number of policy levers at their disposal, they cannot drive the shift to digital manufacturing alone. Many of the pre-conditions for networked production need to be provided in concert with efforts among stakeholders in industry, education, research, and other fields.

5. Opportunities abound for both developed and developing nations.
Networked production offers manufacturing industries in developed nations the opportunity to enhance their competitiveness by becoming more flexible and more efficient. Equally, digital production represents an opportunity for developing nations to maintain or enhance their levels of competitiveness as their cost advantage diminishes in the face of rising labour costs.

6. Networked production is unlikely to decimate manufacturing employment.
Experts forecast that networked manufacturing will drive productivity, but they say that it is unlikely that the shift to next-generation networked production will lead to significant declines in employment. Historically, they point out, gains in manufacturing productivity have had a positive impact on the economy and on job creation.

1 The promise of networked manufacturing

Amid declining manufacturing output in many developed economies, a new opportunity is emerging for industry to compete: networked manufacturing. "If we make manufacturing smarter or more interconnected, we can keep manufacturing in developed economies and help create some innovation around manufacturing," says Christian Reimsbach-Kounatze, an information economist and policy analyst at the Directorate for Science, Technology and Industry at the Organisation for Economic Co-operation and Development (OECD) in France. "Countries such as Germany, which have been strong in the development of machines, see this as an opportunity to take the lead in this next wave of innovation in manufacturing."

In networked manufacturing, the various elements of production systems use data flows to drive better communication, co-ordination, and control. One key element of digital production, according to Mr Reimsbach-Kounatze, is that optimisation of production can be driven across the manufacturer's entire production system. "You have the machines collecting the data," he says, "but because the machines are embedded in a larger context, you have the possibility to optimise the whole system centrally with cloud computing."

Enhanced manufacturing capabilities are a must for developed manufacturing economies such as the US, Japan and Germany. According to Deloitte's 2013 Global Manufacturing Competitiveness Index, these nations already fall behind China in terms of competitiveness; in the next five years, they are expected to fall even further behind. In the past decade or more, the US, Japan and Germany have seen declines in their manufacturing output and manufacturing employment. In the US, manufacturing has declined to 20.7% of GDP, according to data from Deloitte. And in the decade to 2010, 3.1 manufacturing jobs per hundred population disappeared.

In developing nations such as China, there is also a need to improve competitiveness in manufacturing. While manufacturing now accounts for 32.4% of China's GDP, and while 3.1 manufacturing jobs have been created per hundred population in the decade to 2010, continued rapid economic growth is fuelling labour costs. China's private-sector wages rose 14% in 2012 alone, according to data from the country's National Bureau of Statistics. Chinese manufacturers risk losing their competitive advantage if labour costs continue rising in the medium and long term.

A production revolution

Next-generation manufacturing models rely heavily on data. "Sensor technologies, advanced robotics, wireless communication, improved capabilities for data processing and storing big data—none of those things are new," explains Henning Kagermann, president of Germany's National Academy of Science and Engineering. What is different today, though, is that "all the technologies we need are cheap and affordable," he says. "I think we have a kind of a tipping point now."

Networked manufacturing represents a revolution, according to some observers. "We're moving from a push-driven model to a pull-driven model with the consumer becoming much more of a driver in the supply chain," explains Jagjit Singh Srai, head of the Centre for International Manufacturing at Cambridge University's Institute for Manufacturing. "Production systems will be more flexible in terms of handling smaller volumes and mass-customised product portfolios." This flexibility is critical for manufacturers, according to Wilhelm Bauer, acting director of Germany's Fraunhofer Institute for Industrial Engineering IAO: "Recent history shows that a fast and agile response to volatile demand, as well as the ability to produce highly configurable or even individual products, is of vital relevance," he points out.

Dieter Spath, president of Germany-based industrial technology producer Wittenstein, describes how product individualisation today is based either on individualisation in corpus—in the hardware—or individualisation in the software. Many smartphones are assembled by hand because smartphone development cycles are so short that automated production cannot keep pace. In other words, in the 1-2 years that would be needed to start up automated assembly of a new model of smartphone, the handset maker would already have developed the next generation of the phone. "Individualisation of products in corpus needs much more flexibility," concludes Prof Spath. Networked production offers that extra flexibility.

Next-generation manufacturing models also promise many other benefits in productivity or sustainability. Dr Srai believes that networked production may offer "a better understanding of where materials come from, where they go in terms of use and after-use, which will help capture waste and capture inefficiencies." It could mean less material wastage, lower energy consumption, and fewer workplace accidents. According to a survey published in February 2014 by Deloitte China and the China Machinery Industry Federation (CMIF), one-fifth of machinery producers in China see more-intelligent equipment cutting workplace accidents by 50% or more.

According to the Deloitte/CMIF survey, 77% of machinery producers in China agree that developing next-generation manufacturing capabilities is important to their company. Yet even if networked manufacturing may be approaching a tipping point, progress towards establishing digital production is in its infancy. At this stage, few companies have taken steps to begin the shift towards networked manufacturing in their businesses.

Ricky Tung, a manufacturing managing partner at Deloitte China, points out that adoption of networked production technologies among Southeast Asia's manufacturers is low in part because they "feel that they can still enjoy the benefits of low labour costs." Still, he observes, manufacturers understand that these benefits will diminish if labour costs continue rising, and that in the longer term, "they don't have too many options other than to upgrade to make sure they are efficient enough to compete," he says. "It is a game of survival."

2 Conditions that enable networked production

In both developed and developing regions, the shift towards networked manufacturing remains at an early stage. "I have my doubts that there is complete agreement on how to do it and what the key levers are," says Prof Kagermann of Germany's National Academy of Science and Engineering. Nevertheless, experts do agree that there are a number of pre-conditions in a country, region, or industry sector, that may lay the foundations for a successful shift to digital production.

Among these pre-requisites is freedom of trade. To deliver all of the benefits that it is capable of delivering, networked manufacturing must be able to span borders. "It will operate in an open trade environment more successfully than it will operate in a closed trade environment," says Kenneth DeWoskin, a senior adviser for Deloitte China. "Countries that are highly protective of their own markets, that have complex administrative procedures, that don't have responsive trade and manufacturing models, are going to be at a disadvantage." Dr DeWoskin says that free trade agreements among Southeast Asian countries are evolving rapidly.

Sound network infrastructure is another pre-condition. "Networked production will make manufacturing more decentralised and more flexible," says Rudolf van der Berg, an information economist and policy analyst at the OECD. "It will emphasise the need for good infrastructure because it will require just-in-time deliveries, and it will require excellent communication between the plants." For his part, Dr DeWoskin points out that networked manufacturing "is going to require very reliable bandwidth, very inexpensive bandwidth, and fail-proof systems."

Experts also stress the importance of standards governing materials, processes, infrastructure, interoperability and interconnectivity. "There are lots of different, complementary standards and they work pretty well today" says Michael Molnar, director of the Advanced Manufacturing National Programme Office at the National Institute of Standards and Technology in the US. "What we are talking about is making them better, more sophisticated and more comprehensive." Prof Kagermann believes that, "from a technical point of view, we need globally accepted open standards, and we need a reference architecture so that people can deliver and innovate on modules which later sit together." (See box: Who sets the standards?)

Security and protection is also paramount if networked production is to flourish. "Increasingly, ones and zeros become your primary intellectual property, because it defines the product and often the process," says Mr Molnar. As such, networked production requires a sound legal framework governing intellectual property. It also requires "data security, which can involve communications, control and encryption standards, and process information," according to Mr Molnar. To be comprehensive, this security must cover the entire manufacturing system, including manufacturing plants, suppliers and sub-contractors, and logistics operators.

Who sets the standards?

Experts interviewed for this research stress that standards have an important role to play in enabling a successful shift to networked manufacturing. These standards may cover manufacturing processes, production systems, and more. But a critical question remains: Who sets the standards?

Tobias Krause, a researcher at the Fraunhofer Institute for Industrial Engineering IAO in Germany, believes that it should not be developers of proprietary technology such as software firms, enterprise systems providers or communications network operators in isolation that convert industry requirements into standards.

Rather, Mr Krause says, "it has to be a discussion between those companies implementing those standards, and those companies and sectors using it." He points out that, in Germany, the government-led Industrie 4.0 initiative focused on the future of manufacturing provides a forum for such discussion. The initiative brings together federal government, industry, academia, and three different Fraunhofer institutes.

The US also uses an approach based on dialogue between different actors spanning government, industry and research, according to Michael Molnar, director of the Advanced Manufacturing National Programme Office at the National Institute of Standards and Technology in the US. "We do not have a government agency setting the standards," explains Mr Molnar. "The US approach is that the government works with industry to develop standards."

Mr Molnar believes that such a consensus-based approach produces the best outcome. "When you are talking about complicated systems with many players and many stakeholders, such an approach is optimal," he says. "I think in general it takes a bit more time to draw up standards based on consensus, but you arrive at better standards."

Promoting freedom of information, including maintaining open access to the internet, is another pre-condition for a successful shift to networked production. Dr DeWoskin of Deloitte China argues that digital manufacturing requires "free flow of information, the stimulation of innovation, group-ware, group-driven innovation, the ability to communicate, and especially the ability to communicate across borders." Mr Reimsbach-Kounatze of the OECD cautions that there is a risk that individual nations could restrict the flow of information across borders to put up trade barriers.

Skills are also critical in enabling networked production, say experts. "One of the pre-conditions is a skilled workforce that is capable of effectively controlling very sophisticated computer systems," points out Michael Jackson, special advisor for manufacturing to the US Secretary of Commerce. Networked manufacturing has the potential to create attractive jobs in manufacturing, especially for those production workers who have well developed information technology skills. But more must be done to develop these skills. "If the new technologies are going to result in a larger number of good jobs in manufacturing in the US," warns Howard Wial, director of the Centre for Urban Economic Development at the University of Illinois at Chicago, "we really need to bridge the gap between the formal education system and the skills needs of manufacturing."

Clearly, governments have a role to play in promoting networked production. Fully 88% of the China-based machinery producers surveyed by Deloitte China / CMIF indicate that they are expecting their government to further strengthen policies around science, technology and innovation to drive intelligent manufacturing. "Practitioners want to see a lot more detailed policy, guidelines or support coming from the government," says Mr Tung. Yet,

the extent to which governments should drive the shift to networked manufacturing is not clear. "The public sector by itself doesn't have the knowledge to figure out exactly what kinds of problems need to be solved and by whom," points out Dr Wial.

Experts interviewed for this research insist that governments cannot drive the shift to networked production alone. For example, says Mr Molnar of the US Advanced Manufacturing National Programme Office, it is not only important for governments to decide what to do, but also what not to do. In many cases, he argues, industry should take the lead. Nevertheless, governments such as the US administration are formulating national manufacturing strategies that align industry, education and regulators. These efforts, Mr Molnar argues, bring industries "to that tipping point when they see increasing benefits in applying advanced IT technologies to their existing operations, as well as designing their new operations around advanced manufacturing."

3 The economic impacts of digital manufacturing

Initially, networked manufacturing may benefit big companies with access to funds, technologies and research. According to Dr DeWoskin of Deloitte China, it may also benefit manufacturers with business models based on outsourcing, "companies that are already familiar with complicated strategic alliances, multi-player supply chains and substantial outsourcing". As a result, believes Mr Molnar, networked manufacturing could drive "a change from large, vertically integrated companies to more diversified companies that focus on core competencies."

Whilst large companies may be among the first to gain from networked manufacturing, some experts believe that digital production may have more profound implications for small and mid-size firms. Not least, the spread of digital production technology has the potential to reduce economies of scale and lower barriers to entry. Howard Wial expresses it simply: "It means that things that used to be the province of large firms can now be done by smaller firms." Specifically, networked production platforms may enable a diverse range of small and mid-size companies to participate in global supply chains for the first time.

In the long term, access to a sophisticated supply web could transform the opportunities available to smaller firms active in manufacturing. "It's a whole new world for a small start-up or a small manufacturer," Michael Molnar suggests. Where previously such firms may have been hugely capital constrained, "suddenly you can have manufacturing companies with very little capital or no capital, built on collaboration," he points out. Information technology coupled with comprehensive standards have the potential to enable the 'democratisation of manufacturing' or 'virtual extended enterprises', Mr Molnar explains. "It really changes the rules for what small and start-up companies are able to do."

Opportunities for developing economies

Similarly, networked manufacturing could pave the way for greater geographic dispersion of actors in the manufacturing supply web. "The proliferation of computing communications mechanisms naturally leads to decentralisation," says Mr Jackson. As better communication allows wider participation in the supply web, supply chains may become shorter, in turn enabling manufacturers to locate production close to end-markets. Shorter supply chains save time, lower monetary costs, and limit environmental impact too.

As a result, manufacturers may choose to locate more of their manufacturing capacity in, or close to, their major end markets. (See box: Adidas considers mini-factories.) James Manyika, a director at the McKinsey Global Institute in the US, sees opportunities for greater participation in global manufacturing among countries such as Malaysia, Indonesia and Mexico that are located close to the large end-markets of China and the US respectively. As a nation, "you could position yourself as a staging ground, or a final assembly location," he explains. "So even though you may

Adidas considers mini-factories

For an example of how next-generation networked production manufacturing technologies can enable new approaches to manufacturing, consider adidas. The German sportswear maker operates almost no manufacturing capacity of its own, but instead outsources production to contractors that run vast factories in Southeast Asia. Now, though, adidas is considering a fundamental change in its manufacturing model.

The firm says that it is planning to shift production closer to customers in its main end markets in the coming years, by starting up local, flexible manufacturing in so-called mini-factories. As part of its "Speedfactory" research project, adidas is co-operating with suppliers of networked manufacturing equipment, robotics specialists and researchers at higher education establishments in Germany.

While the firm will not discuss the exact technologies that will drive its manufacturing capacity, adidas does say that innovative materials and production processes feature in its plans. The firm also states that its materials suppliers will have to push through operational changes in order to accommodate the smaller production batches that it is planning.

What might be the outcome of such a change to its manufacturing model? Adidas states that its planned move will enable it to reduce its exposure to rising labour costs in manufacturing. Furthermore, the firm believes that its plan will enable it to sharpen its customer focus by offering individualised products.

not be the primary producer, or even the final destination, you can participate as a way point."

Does networked manufacturing represent greater opportunities for developing economies to participate in the global manufacturing economy? Henning Kagermann of the National Academy of Science and Engineering is confident that it does. However, based in his prior experience as CEO of German software firm SAP between 2003 and 2009, he believes industrialised countries may be the ones that stand to benefit most in the beginning. "But later, this knowledge will be distributed," he says, "which I believe will help all countries develop faster in the end."

While networked production promises greater manufacturing flexibility and a host of other benefits, it may also represent a threat to some developing economies that are already a force in manufacturing. "If your differentiation has largely been because you just have cheap labour, then that singular advantage is challenged in this context," explains Dr Manyika of the McKinsey Global Institute. He observes that in China, "you are starting to see early investments in next-generation manufacturing, particularly in robotics and technology," as the nation seeks to become more competitive in the face of rising wage costs.

Employment, of course, is a key consideration for policy makers as manufacturing becomes increasingly automated in both developed and developing economies. Digital manufacturing offers the potential for highly skilled, well paid jobs for those parts of the workforce agile enough to keep pace with fundamental changes in manufacturing technologies, processes and models. Not everyone will manage the transition. "We have to up-skill in order to create new jobs and take all the work force with us," points out Prof Kagermann.

Many stakeholders fear that next-generation manufacturing technologies that build on communications networks and on automation will have a negative impact on employment. "It's possible, but it's not obvious," says Dr

Wial of the University of Illinois at Chicago. "It is also not something that has happened historically." Automated production enables greater productivity—with fewer workers making the same volume of goods—but it also has the potential to increase employment by enlarging the market for those goods. "Historically, productivity growth has been good for economic development and job creation," Dr Wial concludes. "And I don't necessarily see anything about the current wave of manufacturing technologies that are coming online that would make me think that that can't happen again."

Conclusions

In order to bolster manufacturing competitiveness, nations in both developed and developing regions are evaluating the potential of next-generation networked manufacturing. Networked production systems that harness data flows to control and optimise production may enable manufacturing of small volumes and customised production. As such, digital production promises greater manufacturing flexibility and a host of other benefits that may boost both manufacturing and economic growth across the globe.

On the basis of desk research and in-depth interviews with manufacturing professionals, policymakers, and other experts, it is possible to draw a number of conclusions. These include the following:

- The potential benefits of networked manufacturing include more flexible production, greater efficiency and faster time to market. In addition to these benefits, digital production has the potential to promote innovation in other economic activities besides manufacturing.

- Policymakers have the opportunity to drive the shift to networked manufacturing, for example with well-considered policy approaches towards trade, infrastructure, education, and more. Yet governments cannot navigate a successful shift to digital production single-handedly.

- Networked production offers developed economies the potential to step up their manufacturing competitiveness, and developing economies the potential to maintain their edge as labour costs rise. Networked manufacturing may drive a shift of production capacity towards large markets and countries with developed infrastructure and skills.

London
20 Cabot Square
London
E14 4QW
United Kingdom
Tel: (44.20) 7576 8000
Fax: (44.20) 7576 8476
E-mail: london@eiu.com

New York
750 Third Avenue
5th Floor
New York, NY 10017
United States
Tel: (1.212) 554 0600
Fax: (1.212) 586 0248
E-mail: newyork@eiu.com

Hong Kong
6001, Central Plaza
18 Harbour Road
Wanchai
Hong Kong
Tel: (852) 2585 3888
Fax: (852) 2802 7638
E-mail: hongkong@eiu.com

Geneva
Rue de l'Athénée 32
1206 Geneva
Switzerland
Tel: (41) 22 566 2470
Fax: (41) 22 346 93 47

E-mail: geneva@eiu.com