Disruptive Technology, Smart Factories and Economic Development

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A more detailed biography and bibliography is available at the end of this note

Summary

In the last three years, smart factories have opened in Mexico. Others are operating in Mexico, Vietnam, Thailand, and Indonesia. Higher bandwidth connectivity is key in these factories. They connect all manufacturing equipment. These factories rely upon Open Source software and machine learning analytics. Thus, they are more flexible and intelligent than traditional factories. They include software defined applications that manage and optimize operations, permitting such factories to have the freedom to adapt to new lines of business. This allows an auto plant to produce electric cars as well as hybrids.

These plants' employees acquire their skills through apprenticeships or university exchange programs. Higher-level technical employees, graduates of a local technical university, may have participated in a university exchange program in Europe. Smart auto assembly plants produce some of the most sophisticated products, like the Audi Q5 SUV TFSIe. Others are automated components suppliers.

The rise of these plants in developing nations indicates that multinationals are investing in regional hubs to serve important markets. They are investing in Mexico, not only to sell into the United States, but also most of Latin America, China, and Japan. Thus, rather than reducing overseas production due to the fragility of supply chains under COVID-19, international firms have implemented a more targeted regional production and redundant sourcing strategy. This makes it easier to coordinate tens or hundreds of plants because of innovations, such as Open Source-based Kubernetes operational orchestration software that relies upon cloud-based infrastructure.

This trend could reshape the development process and point the way to new economic development models. It creates a framework for developing digital skills that, today, are often concentrated in advanced economies. Training creates digital workers who can interpret the results of AI-based analytic models and insights from machine learning. It creates a factory shop floor where workers implement the results of this analysis. It also results in new ecosystems of digital suppliers and technical advisors that have upskilled their own workforces.

Investing firms and regional governments have created a digital ecosystem for these factories that provides workers with training courses that can number in the thousands as well as years-long apprenticeship programs. This training can include ongoing technical support and incentives for constructing plants and bringing national suppliers into the ecosystem.

Communications connectivity will be of paramount importance in the future as firms employ Open Source software to transfer new insights about processes and operations to interlinked plants across the globe. Southeast Asia already has component suppliers for the auto industry investing in smart factories and tapping into local ecosystems for auto parts. These plants benefit from training and apprenticeship programs as well as national, regional, and local government support for the new facilities. In addition, smart factories are benefitting from the growing regional demand for vehicles in Southeast Asia and China.

Africa is beginning to build some of the local technology infrastructure it needs to attract smart factories. It has much improved international Internet communications. Several nations possess digital centers of excellence. Google has an AI research center in Accra, Ghana. Its Google for Startups Accelerator Africa accepts funding requests from firms in 17 African nations. Google has already trained 2 million Africans in a digital skills training program – it expects to reach 10 million -- and its Launchpad Accelerator Africa supports 100,000 developers and over 60 tech startups. Microsoft has African Development Centers in Lagos and Nairobi. China's Huawei has two data centers in South Africa. Africa still lacks some elements of the technology ecosystem that Mexico and Vietnam have created. With greater support for apprenticeships and training, as well as government programs to advance the digital state of factories, Africa could see smart factories built in its more technology-oriented countries, including Nigeria, Kenya, Rwanda, Ghana, and South Africa.

Building Smart Factories in Developing Countries

It seems unlikely, but some of the world's most sophisticated factories are in developing countries like Mexico.

Audi's auto assembly plant in San Jose Chiapa, Puebla, Mexico, is the first in Mexico to produce "premium", higher performance, higher-priced vehicles, including the first plug-in hybrid SUV, the Audi Q5 TFSIe. This plant's level of automation makes it one of the most sophisticated in the world. While its engines are imported from Germany, the rest of the vehicle is produced locally. Audi exports most of its output to the United States, but it can also ship vehicles to Europe. In fact, the Mexican smart factory produces SUVs previously produced in Germany. In Audi's smart factory's machine learning models are employed to optimize performance and minimize production defects in areas such as metal stamping. These benefit from sensor networks built upon the Internet of Things that examine products for defects and track the location of parts. "Smart logistics" is an important focus for the plant.

How has this happened in a developing country? The Mexican government, as well as its regional and local counterparts, have promoted the growth of digital factories. The goal was to upgrade their labor-intensive manufacturing base to plants that require digital skills, i.e., smart factories. So, these governments financed training programs to upskill employees and give them the ability to handle the results of digital analysis. These governments as well as Audi supported technical enrichment for Mexican engineering graduates so they would have nearly the equivalent of a high-level university education. Audi, Volkswagen, and Mercedes helped Mexico reach its goal of attaining a more digital status through the introduction of the Internet of Things and digital analytics that upgraded its manufacturing sector. The new Audi plant produces about 150,000 vehicles a year with 5200 workers. It has seven suppliers – some of its most important ones -- located in a "just-in-sequence" park adjacent to the facility. It draws upon 180 suppliers, 100 of which are Mexican.

Audi organized a concerted training effort several years before its Mexican facility opened. The costs were shared with local and regional governments. Audi completed 5300 training courses for local employees by 2016, usually in partnership with local universities and technical institutes. It sent more than 750 employees for training in Germany, like what VW does with employees at its U.S. plant in Chattanooga, Tennessee. It developed apprenticeship programs that educated 220 skilled graduates that it hired. Each of these classes included about 80 employees who completed a 3-year apprenticeship.

Other firms have expanded their presence in Mexico. Bosch, a German component supplier, built a smart factory for automotive parts in Celaya, Mexico, near Mexico City. It produces automotive electronic controls and has "state-of-the art intelligent production lines" that collect and analyze production information in real time. Bosch built the smart factory not only because it can easily improve predictive machine maintenance but also since it optimizes production, improving the quality of production. The manufacturing software platform is Bosch's intelligent control system. It receives information from sensors that analytic software interprets rapidly. Bosch plans to introduce its control system to its 10 Mexican plants. Bosch's software and engineering facility in Guadalajara has supported its investments.

Bosch has also opened a smart factory in Hemaraj, Thailand. According to a Bosch board member, this plant represents a localization strategy that lets Bosch serve the increased demand that is driving local and regional auto plants to expand production. This smart factory will automate manufacturing and depend upon data analytics to improve operations. Associates who sit in an "active cockpit" on the factory floor can see production information in real time. The Thai facility also includes an R&D Center where 60 associates are refining gasoline injection systems. The plant already employs 300 associates.

In Vietnam, Bosch has invested 60 million euros to create a smart factory and increase the capacity of its plant in Dong Nai. The plant has been manufacturing pushbelts for continuously variable transmissions.

Last year, France's Schneider Electric launched its first smart factory in Monterrey, Mexico. It relies upon Schneider's EcoStruxure solutions to connect machines. In Monterrey, Schneider's Industrial Internet of Things technologies combine with EcoStruxure infrastructure software to improve the facility's production of motor control centers, enclosed drives, lighting panelboards and safety switches. The system offers an improved view of different steps in manufacturing, utilizing tracking of machine performance on the shop floor in real-time that employees and top-floor management review. The plant's 1,100 employees benefit from the firm's close ties to local universities that conduct teaching and upskilling programs. The universities include the Monterrey Technology University, Tec Milenio, the Autonomous University of Nuevo Leon, and the University de la Valle. The facility has reduced maintenance costs by 20 percent and increased overall equipment efficiency by 7 percent in its first year.

Schneider also opened a smart factory in Batam, Indonesia, in 2019, equipped with sensors on its machines for rapid analysis of their performance. This reduced production errors, increasing productivity.

The shift to a Regional Strategy for Production

Firms locate smart factories in Mexico for three reasons. First, Mexico has many multilateral and bilateral trade agreements. This has fueled Mexico's rise to the 12^{th} largest exporter in the world, with exports worth $472 billion in 2019. It has signed 14 free-trade agreements with more than 50 countries that represent 40 percent of world GDP. This includes the European Union, Japan, China, and the United States.

Second, smart factories let firms localize to serve markets in regions where demand is growing. Articles about Bosch's smart factories in Mexico, Thailand, and Vietnam, clearly identify the firm's pursuit of this strategy. It is also at the heart of Audi's and Schneider Electronics' investment in smart factories.

Third, new, Open Source software orchestration technologies such as Kubernetes permit firms to harmonize operations between plants including across geographical boundaries. Other industry efforts, such as Microsoft's work with BMW and Bosch to create an Open Manufacturing Platform, are developing new standards for the deployment and use of new software technologies and improvements in data analysis.

Smart Factory Investments in a Global Context

Some economists believe that COVID-19's exposure of the fragility of global supply chains will result in a retrenchment of globalization, with many suppliers relocated to developed countries. This seems to overlook multinational firms' efforts to expand their "span of control".

Economic historian Alfred Chandler analyzed how large U.S. firms became so central to the U.S. economy in the early Twentieth Century. He contended that the challenges of operating complex industrial operations initially overwhelmed firms like DuPont. Once they developed a multidivisional structure that separated strategy from daily operations, they operated efficiently mainly due to expanding their "span of control" over a wide-ranging set of operations. While vertical integration and new technology reduced this "span of control", contemporary emerging technologies such as Open Source orchestration software that facilitates global harmonization among facilities appears to be broadening firms' global span of control.

If this new trend is well-founded, new technologies that permit countries to attract smart factories may reshape economic development. This shift could help countries improve their manufacturing bases. In the process, their manufacturing capabilities might leap over several stages in traditional development, such as low-wage assembly and even slightly more automated, but not digital assembly. This might permit countries to advance rapidly if they employ apprenticeships, training, and exchanges of engineering school graduates to upskill large numbers of workers that run smart factories efficiently. These smart factories are often tied to an R&D facility as well as to respected technical universities.

Key things that countries, regional governments and local businesses need to recognize are that:

1. Higher level skills – data analysis and interpreting the results of machine learning models -- can be acquired with apprenticeships and engineering exchanges.

2. A relationship with a technical university is essential.

3. Trade relationships with other nations are crucial. Mexico is well-connected for trade with Europe and Japan as well as low tariffs with most of the Western Hemisphere.

4. Localization is likely to be prioritized by global firms. They will want to serve geopolitical areas with more customized products (here, vehicles) that conform to regulatory and cultural expectations. There is a recognition that this trend will begin during the next phase of internationalization.

5. There can be real economies that result from emerging technologies. They facilitate harmonizing production at hundreds of plants worldwide. They also offer job opportunities suitable for an emerging digital economy.

To attract smart factories, national, regional, and local governments should:

1. Create the first stage of an ecosystem of suppliers and technical training capabilities that can support a smart factory.
2. Create ties or links to a technical university or technical college that can assist with apprenticeships and additional training. In Africa, Google has initiated a substantial effort to improve digital skills.
3. Upgrade communications so that a factory has high bandwidth connections to other firms in its ecosystem.
4. Offer trade access to regional markets and possibly global markets.

These changes will alter the reasons for investment in developing countries:

1. Skills will be the key to attracting new investment, not low wages. Digital skills permit smart factories to operate without a substantial imported staff.
2. Investments that are part of an integrated global ecosystem of production will be more important than participation in a supply chain. Smart factories that produce transmissions or engines will be more valuable to a global manufacturing ecosystem than those producing labor intensive, less-complex products.

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Biography

Dr. Robert Cohen is an economist and senior fellow at the Economic Strategy Institute, where he directs a study of the impact of cloud computing, machine learning and artificial intelligence on the U.S. economy. His current research is on the impact of moving to an "intelligent" software economy. This project analyzes the economic impact of firms deploying cloud services, the Internet of Things, artificial intelligence and machine learning. He argues that this combination of the "intelligent" software services – cloud, software, AI and ML -- is a pervasive General-Purpose Technology that will reshape the economy as electricity and the internal combustion engine did in the Twentieth Century.

Dr. Cohen employs input/output analysis to forecast US investment and productivity changes and employment impacts. Cisco, Industria Macchine Automatiche S.p.A, the Berggruen Foundation, the Ewing Marion Kauffman Foundation, Brocade Communications and the OECD have sponsored his recent work. Dr. Cohen's studies of the impact of grid computing on North Carolina and the US used a similar approach, with support from the NC Rural Internet Access Authority, IBM, AT&T, Intel, Juniper Networks, MCI, Corning, Applied Materials, and Cadence. With support from Japan's AIST, IBM, Cisco, NTT Data, and Intel, Dr. Cohen repeated this analysis for Japan.