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The Digitalization of the U.S. Labor Market: Lessons from Technology Adoption and Advanced Manufacturing Initiatives in Indiana

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Introduction

Technology change is a global economic trend that has been affecting the U.S. labor market for decades, in ways both positive and negative with relation to the employment resiliency and overall job creation. In order to better understand the broader implications that technology change has on global and U.S. labor markets, this paper will analyze the changing skill mix and skill requirements of occupations within the Manufacturing (NAICS 31 - 33) industry sector. As an employment industry, occupations within the manufacturing industry are declining broadly at a rate of 17.6% (highlighted below), which is attributed to occupations with concentrated work tasks that are susceptible to automation, and ultimately replaced by industrial automation technology. Opposing the occupation decline in the industry are growth opportunities in technology-related roles such as Industrial Machinery Mechanics that have increased employment by 85% between 2002 (213k jobs) and 2022 (393k jobs).[1] This paper will analyze industrial automation trends across global and United States markets, while also positioning a practitioner perspective from innovation and digital transformation activities of manufacturers within the State of Indiana to provide a unique view of firm-level impacts and propose potential data tools to address technology change and skills mix policies and practitioner engagement.

Brief Background of Technology Adoption Among Industrial Firms

While many of the leading global thought leaders have referenced the term "Future of Work" in popular fashion over the last 20 years, technology change has been impacting this "future" and transforming work tasks in large form since the integration of computing technology within industrial markets since the late 1960s via the 3rd Industrial Revolution. As an example, Programmable Logic Controls (PLC), created in 1968, were largely adopted and deployed in American automotive sectors throughout the 1970s and 80s. As industrial leaders transitioned from legacy relay machines to much more efficient PLCs to control signaling between industrial equipment and computers, a spark in American manufacturing was set that is still influencing technology adoption in the modern labor market. Many technology related industrial skills such as program coding, relay monitoring, and more were rooted in work tasks presented via Industry 3, and found even modern conventions via work functions transitioning from manual to robotic such as welding throughout the 1980s, 1990s and even today, The consistent presence of PLCs technology in the industrial setting demonstrates the lasting digital transformation within one of the United States' core economic markets and the importance of building digital and technology skills within the American workforce. The Fourth Industrial Revolution (commonly referenced as Industry 4.0) ushered in a connected factory, in which cloud-, and Industrial Internet of Things (IIoT)-related technologies enabled software and hardware technologies to be interconnected, and enabled interoperable technology

[1] Lightcast Q1 2023 Data Set

operations.[2] Smart technologies such as Machine Learning, Artificial Intelligence, and others emerged as plants moved from human signaling/instruction requirements to operate technology to sophisticated programming now enabling technologies to operate themselves and interested with other technology and humans alike as work tasks were carried out more efficiently and effectively. This proliferation of smart technologies changed the skill mix requirements of employees across all functional types, ranging from frontline production to engineering and supply chain managers, in which nearly all employees must comprehend and carry out computing and digital work tasks now integrated in their day-to-day. Reiterating the previously mentioned example of PLC technologies, earlier adopters of smart manufacturing technology were largely large manufacturing enterprise firms (including as major automotive OEMs GM, Ford, and more for example), but in past few decades many suppliers of these large enterprises have accelerated adoption of similar technologies, now hiring their own robotic welding and PLC technicians, and industrial engineers with smart manufacturing functions.

U.S. Manufacturing Sector Employment Landscape

In 2002, Manufacturing occupations (categorized within NAICS codes 31 - 33) accounted for 15.2M jobs in the United States and 588k jobs within the state of Indiana. 20 years later, in 2022, Manufacturing occupations accounted for 12.5M U.S. jobs and 533k Indiana jobs, 17.6% and 9.4% respective declines in industry employment. For context, the U.S. and Indiana labor markets witnessed 14.8% (19M jobs added) and 8.1% (230k jobs added) respective job growth across all industries during that same period of time.[3] While many factors, such as global offshoring trends, contributed to the steep declines in Manufacturing occupations, one key driving force for the changing employment landscape was the digitalization of the American factory. When analyzing employment data within Indiana, occupations that are categorized as highly susceptible to automation such as *Helpers-Production Workers* (SOC 51-9198) employed 16.8k jobs in 2002, but decreased by 64% to 6.1k employment in 2022 and *Machine Feeders and Offbearers* (SOC 53-7063) decreased employment by 3.7k or 60% over the same 20 year period. In contrast, *Industrial Engineers* (SOC 17-2112) saw 115% growth from 4.9k to 10.6k employment over the 20-year period and *Machine Tool Setters, Operators, and Tenders, Metal and Plastics* (SOC 51-4081) added 3k jobs, or 63% growth. There is a tale of two occupational profiles with relation to employment growth and decline within manufacturing, when analyzing Indiana's labor market. Roles that include skills related to computing, programming and technology largely witnessed increases over the last 20 years, while occupations that are highly routine, and monotonous in nature declined. This duality of employment growth and decline is

[2] Transforming advanced manufacturing through Industry 4.0. McKinsey & Company, July 27, 2002. https://www.mckinsey.com/capabilities/operations/our-insights/transforming-advanced-manufacturing-through-industry-4-0

[3] Lightcast Q1 2023 Data Set

spurred by industry technology adoption. With many of the approximately 9,000 Indiana manufacturing firms embracing Industry 4.0 technologies such as robotic welding, collaborative robots, machine vision systems, IIoT sensors and more, the skill mix necessary to carry out work tasks has largely shifted toward digital and technology skills.

Technology Adoption Accelerates to Record Levels Among Global Firms

Manufacturing factories across the world are going digital, codified via numerous national initiatives such as the World Economic Forum's 4th Industrial Revolution research initiatives and global forum research such as the International Federation of Robotics (discussed below).While global Automotive industry leaders such as General Motors, Ford, Toyota and others have been introducing industrial robotics to their facilities since the 1960s with the introduction of PLCs and more, Small and Medium Enterprise (SME) firms have steadily embraced automation in a more rapid fashion since the early 2000s, and accelerated their adoption during the Covid-19 Pandemic, as historic labor shortages and supply chain disruptions caused to rethink their production practices. McKinsey and Company reported that the 2020 pandemic allowed for firms that already scaled Industry 4.0 technologies to be seen as "winners" in their respective industries, while firms that had yet to adopt digital technologies at scale received a "reality check." Via a 2020 global industry survey, McKinsey found that companies that had more mature Industry 4.0 implementation conditions reported stronger abilities to respond to pandemic challenges on their labor force, supply chains and more.[4] Industrial automation and robotic associations that track industrial robotic investment activity via global automation equipment manufacturing reporting have cited historic levels for firm investments in 2021. In fact, the International Federation of Robotics cited that robotic installations across all global industries reached a record level of 517k robot installations worldwide, representing 31% growth from 2020.[5] These investment trends are reflected in the United States as well, as the Association for Advancing Automation made note that robotic installations in the U.S. alone increased by 11% from 2020 to 2021, with 44k total industrial robots being installed within firms.[6] The trends continue to reaffirm notions that automation will continue to be on the rise and that firms across all global markets will continue to accelerate technology adoption.

State Economic Development Supports Growth of Firm Technology Adoption

[4] COVID-19: An inflection point for Industry 4.0. McKinsey and Company. How the pandemic transformed digital manufacturing—and vice versa | McKinsey January 15, 2021.
[5] World Robotics Industrial Robots 2022. International Federation of Robots. 2022. https://ifr.org/img/worldrobotics/Executive_Summary_WR_Industrial_Robots_2022.pdf
[6] North America Sees Record Robots Sales in 2022, Association for Advancing Automation. February 24, 2023. https://www.automate.org/news/north-america-sees-record-robot-sales-in-2022

At the local, regional and state levels, public-private leaders mobilized to support Industry 4.0 technology adoption via state economic development funds and resources. The State of Indiana's Governor Eric Holcomb and the Indiana Economic Development Corporation piloted a Manufacturing Readiness Grants Program during Summer 2020 with American Rescue Plan Act (ARPA) federal funds to offset technology enabled capital equipment investments for firms, ranging from investing in their first robotic welding systems, to Industrial Internet of Things (IIoT) connectivity technology and more. The program has since scaled rapidly. Support via the Manufacturing Readiness Grants Program in Indiana has resulted in $45M of grant funding supporting 425 industry projects, unlocking $509M in technology-enabled capital projects and equipment investments through March 30, 2023.[7] The State of Connecticut piloted in the Summer of 2020 and launched a Connecticut Manufacturing Innovation Fund Voucher Program, which facilitates up to $100k in grant funding for Industry 4.0 technology investment. Since Indiana and Connecticut launched their Industry 4.0 investment programs, comparable state-funded economic development grants programs have been launched in states including Iowa, Maryland, Michigan and Wisconsin. While tax incentives and innovation programs utilizing state funds are nothing new, the proliferation of state-funded Industry 4.0 equipment investment programs targeting Small and Medium Enterprise manufacturing firms certainly signaled a call to action for small and medium firms to get in the race for manufacturing modernization.

Firm Technology Adoption Leads to Requisite Digital & Technology Skills Mix

With the rapid expansion of industrial automation, the tasks and functions of workers changed just as quickly. The Brookings Institution recently provided updated research on worker role impacts in which The Institution analyzes the rapid "digitalization" of work that has been occurring over the last decade. Brookings defines digitalization as "the infusion of digital skills (though not necessarily higher-end software coding) into the texture of almost every job in the economy. Through analysis of unique occupational survey data available via O*NET (U.S. Department of Labor occupational information database), the analysis shows that the digitalization levels, or job requirements for relatively robust knowledge of computers and electronics, of U.S. occupations rose from 9% of all 2002 jobs, to 26% of all jobs in 2020 - in short 1-in-4 jobs now require high levels of digitalization.[8]

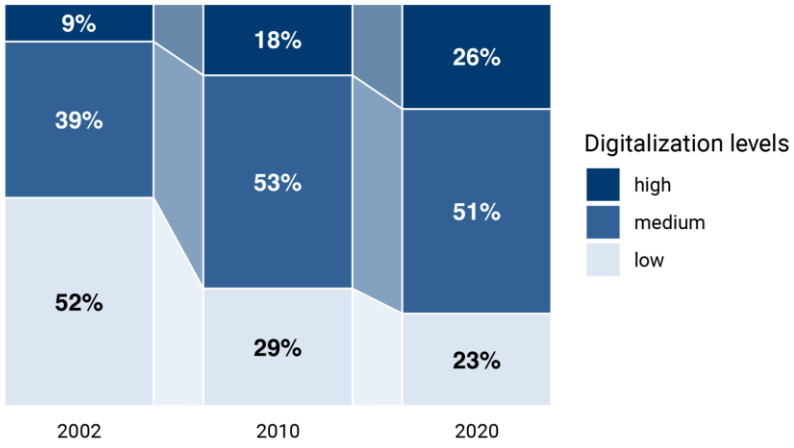
[7] Indiana Manufacturing Readiness Grants, Conexus Indiana, https://www.conexusindiana.com/drive-industry-success/manufacturing-readiness-grants/. Accessed: March 30, 2023.

[8] As the digitalization of work expands, place-based solutions can bridge the gaps, Brookings Institution. As the digitalization of work expands, place-based solutions can bridge the gaps (brookings.edu) February 7, 2023.

FIGURE 1

Share of U.S. employment by levels of job digitalization

2002, 2010, and 2020



Source: Brookings analysis of O*NET and Lightcast data

Brookings Metro

Toyota Motor Manufacturing Indiana Launches Advanced Manufacturing Technician Program that Incorporate Skill Mix related to Industrial Automation & Robotics

In 2012, Toyota Manufacturing demonstrated a major talent need for both their firm in Princeton, IN that employs approximately 7,500, as of May 2023, workers, and for Indiana's broader manufacturing workforce. The company developed an Advanced Manufacturing Technician (AMT) training initiative, which sources talent directly from K-12 pipelines and places students within 2-year USDOL Registered Apprenticeship programs where the students gain mastery skills in Electrical, Mechanical, Fluid Power, Fabrication, PLC, and Robotics competencies. Students start at hourly wages in the high-$20s (per hour) to increase their wages as skill mastery is demonstrated both within on-the-job-training as well as with related training instruction via credits earned at Vincennes University (or Ivy Tech Community College for employers in other regions). As of December 2022, the program specifically operating for Toyota has matriculated 203 students, with 128 graduating and 106 being hired since 2013 within their company.[9] After proving their concept for the AMT Program, Toyota collaborated with the Indiana Manufacturers Institute and the Manufacturing Institute to launch the Indiana Federation for Advanced Manufacturing Education or INFAME as a state-wide program. Since launching INFAME, approximately 10 additional Indiana manufacturing firms, ranging from small to large enterprise firms, have launched programs within various regions of the state, ranging from steel fabrication firms such as Steel Dynamics, Inc. to precision medical device

[9] Indiana Federation for Advanced Manufacturing Education. Indiana Manufacturers Association. https://www.indianafame.com/

firms such as Zimmer Biomet. Firms across the state have been validating the need to train the manufacturing sectors' future workforce to demonstrate mastery and comprehension over a skill-mix of competencies that include robotics and industrial programming. After success in Indiana, the Manufacturing Institute has also scaled the AMT Program nationally within a program now called FAME or the Federation for Advanced Manufacturing Education.[10]

Indiana Small Enterprise Manufacturing Firm Embraces Automation

While many manufacturing firms steadily embraced automation prior to the COVID-19 Pandemic, the onset of the pandemic greatly accelerated Industry 4.0 and robotics adoption across manufacturing firms of all sizes, ranging from small to large enterprises. Citing historically low national unemployment rates, companies such as Elkhart,IN-based Marson International - which employs approximately 125 people - turned to industrial automation and Industry 4.0 technologies to meet customer demands. Marson received a major automotive contract to provide automotive parts to Swedish car maker, Volvo. The firm needed to increase their production capabilities and capacity to meet quality standards of Volvo, and therefore invested in Computer Numerically Controlled (CNC) tube bending, robotic buffing and additional industrial robotic technology. With many of their current production processes being manual in nature, the firm collaborated with regional workforce and community college partners to establish U.S. Department of Labor Robotic Technician & Industrial Maintenance apprenticeship programs. The firm ultimately hired 6 individuals to join their new apprenticeship programs, which embedded key automation industry recognized certifications via academic training at the regional Ivy Tech Community College within their Smart Manufacturing & Digital Integration Academic Certificate program.[11]

Implications for Labor Market Data Tools & Practitioners

The above industry training highlights and employer examples are shared to demonstrate the changing environment of technology skill requirements that are growing in demand and requirement for manufacturing employees across all functions. Several data tools currently exist to aid labor market, workforce and economic development practitioners in projecting and planning for workforce-related programming and policy development. O*Net currently houses skill filter lists for "Hot Technologies" across occupations that shows in-demand technology-related skills within the labor market.[12] In analyzing technology skills list, site visitors are able to

[10] Federation for Advanced Manufacturing Education. The Manufacturing Institute. https://www.themanufacturinginstitute.org/workers/fame/

[11] Marson International taps grants, apprenticeships to meet demand. Conexus Indiana. https://www.conexusindiana.com/2022/04/marson-international-taps-grants-apprenticeships-to-meet-demand/ April, 11, 2022.

[12] National Center for O*NET Development. Hot Technologies. O*NET Online. from https://www.onetonline.org/search/hot_tech/. Accessed: May 12, 2023.

view that programming languages such as SQL, Python hold 1M plus job postings, respectively across the country, which are relevant to the above Industry 4.0 technologies. The O*Net "Hot Technologies" data tool references Lightcast job posting data as the primary data source, which demonstrates opportunities for further real-time labor market data integrations to allow data that have the ability to respond rapidly to industry trends. Lightcast also provides highly relevant labor market data tools and incorporates an Automation Exposure Index score methodology within their tools. Data via the "Hot Technologies" data set show site users what skills are in demand in aggregate, nationally. Revising that dataset within publicly accessible, regional clusters of skills by industry and occupation families would provide greater utility for local, regional and state practitioners to utilize in their work.

Recommendations for Labor Market Data Tools: Below are recommendations for future labor market tools development.

1. **Strengthen Labor Market Tools to Include Enhanced Realtime Applicable Analyses & Data Functions Aligned w/ Regional Technology Skills & Occupation Clustering**
   Challenge: (1) *Practitioners & Policy Makers* struggle to identify the current in-demand digital & technology skills related to career pathways and industry partners. (2) *Employers* struggle to benchmark occupations and training needs within their industry given lack of readily accessible occupational data tools.
   Field Example: Small and medium size manufacturing firms begin accelerating their adoption of programming/coding enabled smart technologies and are required to retrain incumbent workers and hire/train new workers around key technology functions/skills and the demand for PLC and robotic related technicians increases. Economic and workforce development would be able to better support industry by learning about the increase in demand in real time via job posting data that would show an uptick in skill requirements for PLC, programming and robotics functions, the economic and workforce practitioners would then be able to match the employers hiring for the roles training providers in the region who would be able to connect current students and train future workers in these emerging demand areas.
   Data Solution: Enhance overall suite of publicly accessible data tools that enable map and filter functions that enable in-demand technology skills to be broken down within industry sector and related to in-demand occupations. Provide geographic filter to state and county levels.
   Functional Use: *(1) Practitioners & Policy Makers* may utilize to inform education, training and funding programs to meet future technology skill related *occupations. (2) Employers* may utilize to filter identify required skills based on technology investments

and utilize O*NET occupational data to develop training plans and industry comparable job descriptions.
Data Sources: O*NET; Lightcast

2. **Strengthen Current O*NET Survey & Occupational Data Update Methods and Practices**
   Challenge: Current methods for updating occupational data within O*NET are relatively unknown to regional and local economic, workforce and industry professionals. Many of these stakeholders would be able to support the updating of occupational data to include more representative samplings of employer input across the U.S.
   Field Example: States across the U.S. are supporting small and medium size firm adoption of technology and have clusters of employers that would be able to support O*NET occupation data updates. Involving more local/regional stakeholders in these processes would 1.) improve occupational data accuracy and 2.) increase the utilization of tools by a broader array of stakeholders.
   Data Source/Current Process: O*NET currently conducts occupational review and update periods for occupational data, but the frequency and overall processes involved is not actively highlighted on the O*NET site.
   Data Source: O*Net

3. **Develop Digitalization Score/Measure Within Occupations to Demonstrate Job Technology-Related Outlook Measure**
   Challenge: (1) *Practitioners and Policy* have a limited knowledge of the impact that industrial robotics have on workers. There could be some type of resource developed that models data showing occupations that are highly exposed to industrial robots, and would in turn require technology/digital skills mix to ensure individuals are successful.
   Data Source: International Federation of Robotics; BLS
   Article Resource: [The Evolving Impact of Robots on Jobs - John Chung, Yong Suk Lee, 2023 (sagepub.com)]