Technology Use in US Manufacturing

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11 June 2024

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EDA UMaine Staff Paper 2024-114: Technical Report[5]

June 2024[6]

Abstract: This paper examines the technology use of US manufacturing businesses. Results from a 2023 survey of US manufacturers (n=268) show that computer-aided design (CAD), numerically or computer-controlled machines, and programmable controllers / programmable logic controllers have considerably higher adoption rates than Industry 4.0 technologies such as virtual and augmented reality, robots, and AI / machine learning. The most frequently cited barriers to the use of Industry 4.0 technologies are the size and needs (e.g., "products don't require technology") of a company more so than concerns about various aspects of technology (e.g., fear of obsoletion). When selecting technologies to use, US manufacturers consider the impacts of the technology on production and the business (e.g., enhance product quality, increase worker productivity) and costs (reduce production costs, costs of purchasing the technology) more so than the skills of workers and recommendations of (or use by) other businesses, industry associations, colleges, or universities. Future research using the survey data will provide a more in-depth analysis of technology use and its broader impacts on businesses and the regions where they are located.

Technology Use in US Manufacturing

1.   Introduction

        Technology is an important driver of productivity and differences in technology between nations and regions are a big reason why standards of living differ across places. At the scale of an individual business, a company's technology determines the interaction between the skills and abilities of its workers and the amount of goods and services made by the business, as well as how they are produced. For example, a business that uses very little (or outdated) technology generally has less output per worker than a business that uses more (or more up to date) technology.

        In addition to making workers more productive, technology is sometimes a substitute for labor. This means that some types of technology reduce the number of workers that a company needs to employ (West 2015; Dinlersoz and Wolf 2023). In the United States, industrial employment fell by 38 percent between 1980 and 2022, yet US industrial production increased by 104 percent over this period.[7] This large increase in production, despite a reduction in industrial employment, is suggestive of a 227 percent increase in US industrial productivity from 1980 to the present (Figure 1)—with a 47-percent increase in productivity from 2000 to today. Although the acquisition of worker skills and human capital—and the influence of regional factors such as urbanization and industry clusters—impact the productivity of workers, technology

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[7] Industrial employment is calculated as the sum of employment in mining, manufacturing, and utilities (e.g., electric, gas, and sanitary services in the years prior to 1998), using data on full-time and part-time employment from the US Bureau of Labor Analysis. Industrial production data are from the Board of Governors of the Federal Reserve System, retrieved from FRED (Board of Governors of the Federal Reserve System 2024).

change is responsible for a large portion of the increased productivity in US industrial output over time. Indeed, research from the Brookings Institution asserts that technology (e.g., automation, robotics, and advanced manufacturing) is "one of the reasons" for a "resurgence" in US manufacturing (West 2015, 2016).

Figure 1. US industrial productivity increased by over 200% from 1980 to today.
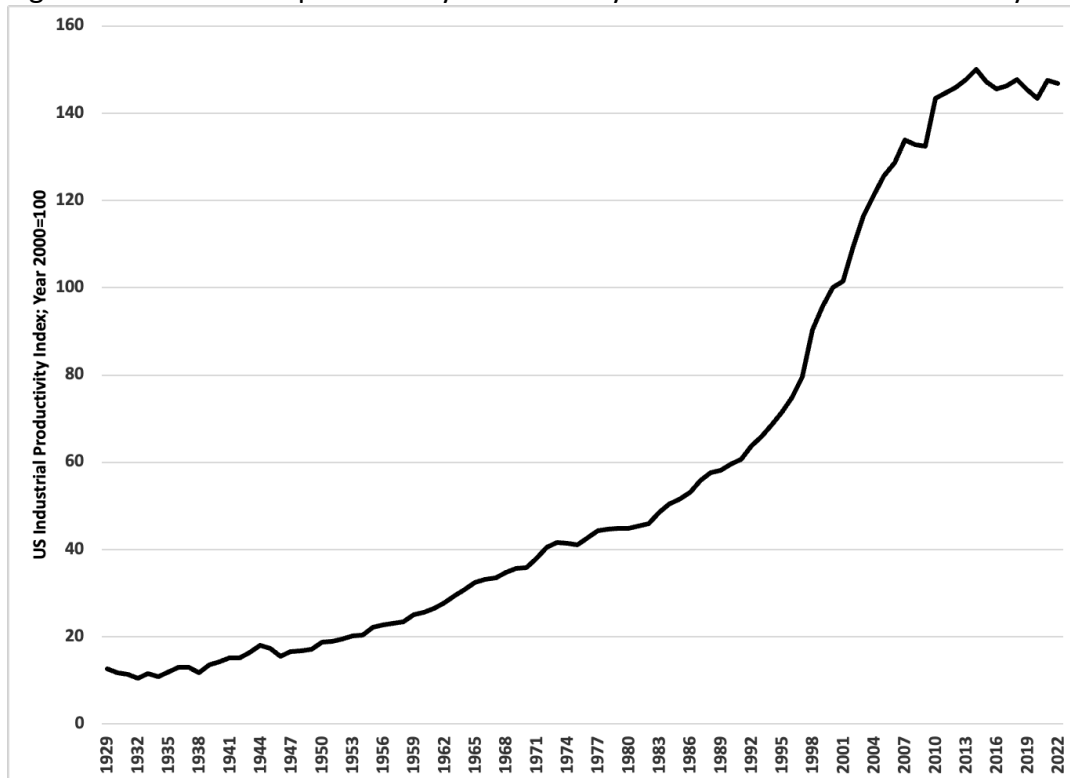
Note. The index of US industrial productivity is measured as US industrial production, using data from the Board of Governors of the Federal Reserve System, divided by industrial employment calculated as the sum of employment in mining, manufacturing, and utilities.

This paper examines the technology use of US manufacturing businesses. Specifically, we look at the types of technologies used by US manufacturers, the perceived barriers to technology use, the ways in which companies learn about technology, and the factors that are considered when selecting technologies to adopt. The analysis is based on a survey of US manufacturers

conducted at the end of 2023 (see appendix for more details about the survey). In the sections that follow, we provide a relatively straightforward presentation of the survey results, with some additional basic analysis of the data. Future research using the survey data will provide a more in-depth analysis of technology use and its broader impacts on businesses and the regions where they are located.

2.   Survey Results

2.1   Technology Use by US Manufacturers

Adoption rates by US manufacturers vary widely depending on the type of technology considered (Figure 2). Over one-half (54 percent) of the US manufacturers in our survey use computer-aided-design (CAD) technology, and about one-third use the technologies of numerically or computer-controlled machines (36 percent), programmable controllers / programmable logic controllers (33 percent), and 5-G Internet (31 percent).[8] The most used technology, CAD, is also among the oldest technologies covered in the survey.[9] In fact, a 1996 survey of rural manufacturers found that 45 percent of manufacturers in nonmetropolitan areas (and 54 percent of manufacturers in metro areas) used CAD at that time (Gale et al. 1999). Other important technologies revealed by the 1996 rural manufacturers survey include numerically or computer-controlled machines (51 percent of nonmetro and 53 percent of metro area

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[8] The estimate of 54 percent of US manufacturers that use CAD has a margin of error of "plus or minus" 6 percent, using a 95-percent confidence level. This means that we're "95 percent confident" that between 48 percent and 60 percent of US manufacturers use CAD technology. The estimates presented in the rest of the paper have margins of error that are no more than "plus or minus" 6 percent. The survey results presented throughout the paper are weighted by the employment size of the business (see data appendix for more details).

[9] According to Tornincasa and Di Monaco (2010), the first-generation CAD systems were developed in the mid 1960s, and commercial CAD use began in the 1970s.

manufacturers) and programmable controllers (47 percent of nonmetro and 44 percent of metro area manufacturers). These two technologies, with widespread use almost 30 years ago, have the second and third highest adoption rates in the 2023 survey.

Figure 2. Over one-half of US manufacturers use computer-aided design (CAD).
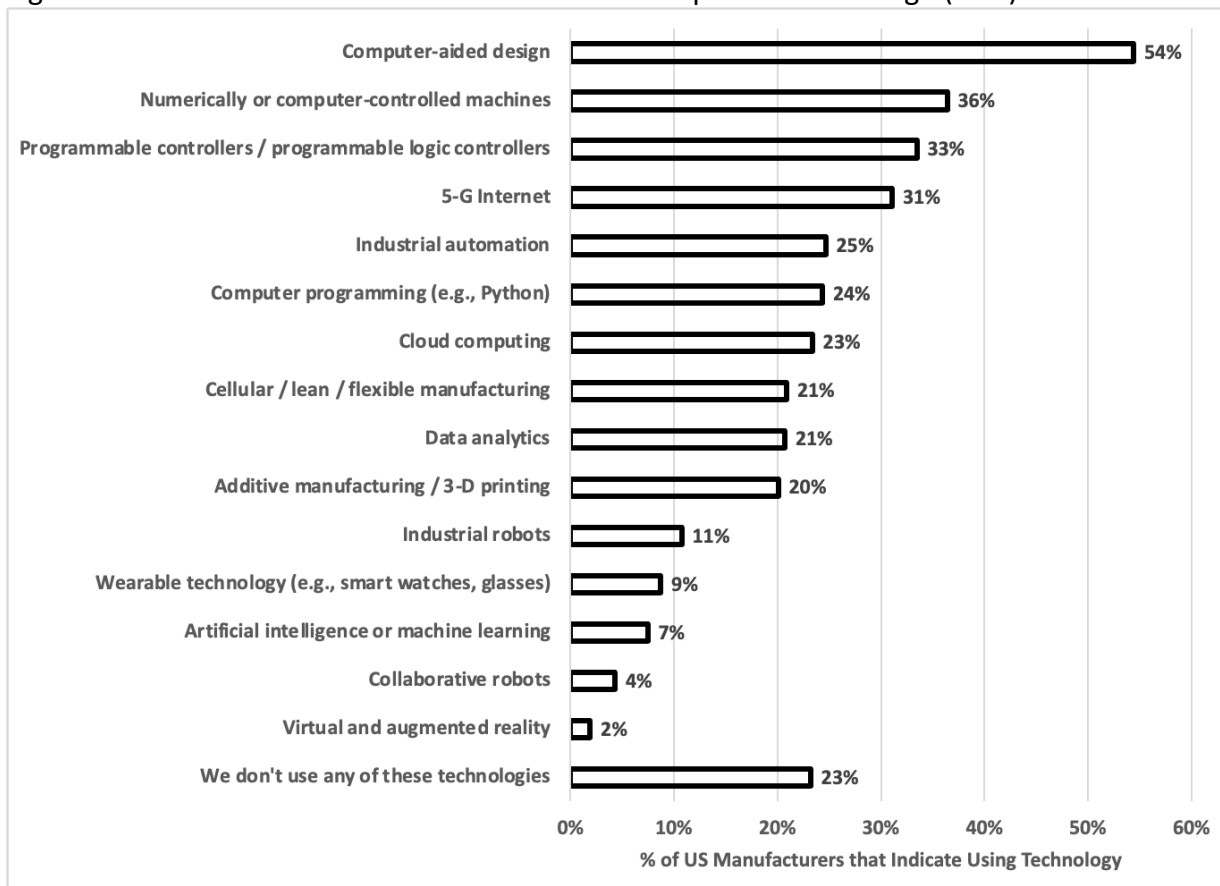
Notes. Data are from a 2023 survey of US manufacturers, n=268. Survey responses are weighted by business size.

In the 2023 survey, between 20 and 30 percent of US manufacturers indicated using industrial automation (25 percent), computer programming (24 percent), cloud computing (23 percent), cellular / lean / flexible manufacturing (21 percent), data analytics (21 percent) and additive manufacturing (i.e., 3-D printing) (20 percent). Also, almost one-quarter of the businesses surveyed noted that they do not use any of the technologies listed in Figure 1.

Technologies used by fewer than 1 in 5 of the US manufacturers covered by the survey include virtual and augmented reality (2 percent), collaborative robots (4 percent), AI or machine learning (7 percent), wearable technology (9 percent), and industrial robots (11 percent).[10]

2.2   Barriers to Technology Use

Another survey question about technology adoption probed companies about the barriers to technology use (Figure 3). In particular, the question asked specifically about the barriers to using Industry 4.0 technologies, which were described to respondents as technologies that "use computers, automation, data, artificial intelligence, and machine learning in manufacturing."[11] We focused on the barriers to using Industry 4.0 technologies—and not technology use of any sort—because the widespread availability and use of older technologies (e.g., computer-aided design) suggest that these well-established technologies have very low barriers to use.

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[10] A 2018 technology use survey conducted by the US Census Bureau found that 6.6 percent of all US firms use "some form of AI in the workplace" (Zolas et al. 2021). The 7-percent adoption rate for AI or machine learning in our 2023 survey applies to US manufacturing businesses.

[11] The survey question asked companies to indicate the factors that "have at least a moderately negative impact (i.e., barrier) on the use of Industry 4.0 technologies."

Figure 3. About one-half of US manufacturers think they're too small to use technology
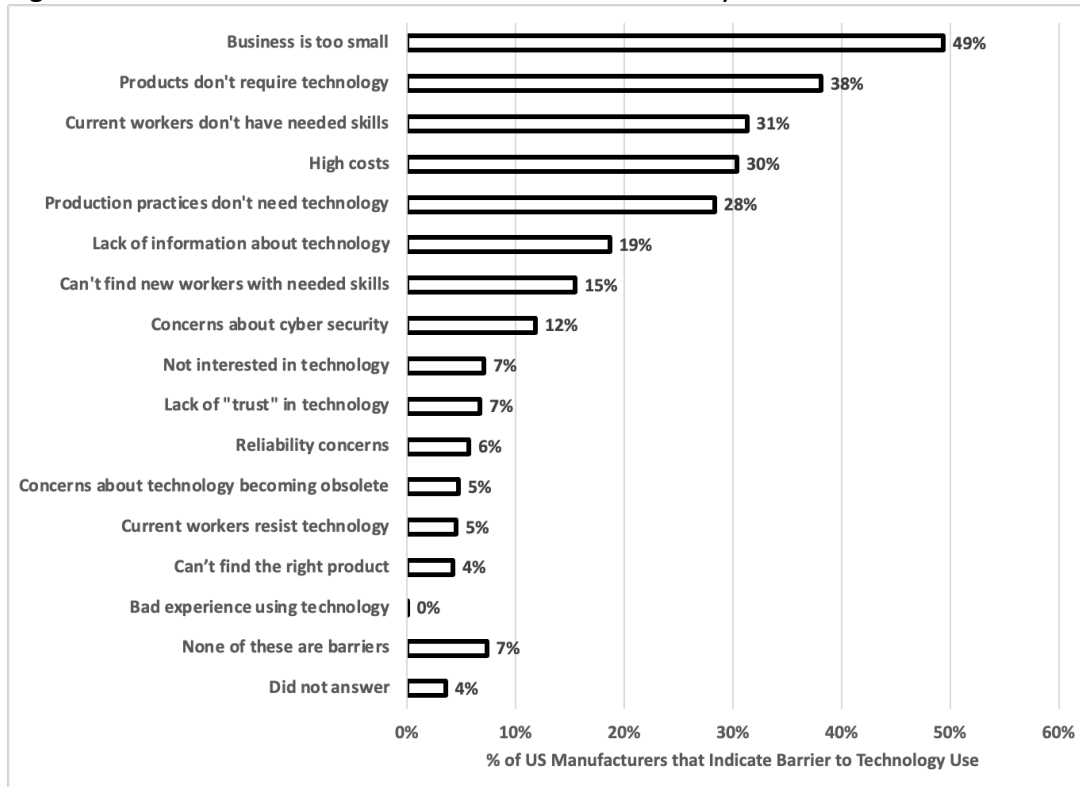
Notes. Data are from a 2023 survey of US manufacturers, n=268. Survey responses are weighted by business size.

The most common reason why the US manufacturers in our survey do not use Industry 4.0 technologies is that the business is too small (49 percent), followed by the perception that the product (made by the company) does not require technology (38 percent), the skill set of current workers (31 percent), the high costs of Industry 4.0 technologies (30 percent), and the perception that the production practices (used by the business) do not need technology (28 percent). Also related to a company's workers, 15 percent of US manufacturers noted that an inability to find new skilled workers is a barrier to Industry 4.0 technology, and 5 percent indicate that current workers resist the use of technology. A comparison of these three questions that deal with workforce issues suggests that a lack of worker skills (both current and future employees) is

a larger perceived barrier to Industry 4.0 technology use than the attitudes of workers (i.e., resist the use of these technologies).

Among the least cited barriers to technology use are a bad past experience using technology (close to zero percent), an inability to find the right product (4 percent), concerns about the technology becoming obsolete (5 percent), and concerns about the reliability of Industry 4.0 technologies (6 percent). A common theme expressed by the US manufacturers covered by the survey is that relatively small percentages cited the "negative" aspects of technology use as barriers (e.g., concerns about reliability, bad experience, concerns about obsoletion) but rather the main barriers to the use of Industry 4.0 technologies are a perception that the company does not need them (i.e., products don't require technology, too small) and, to a lesser extent, issues related to workforce skills (both current and future workers).

2.3   How US Manufacturers Learn About Technologies

The most common way that the US manufacturers in our survey learn about technology is through online and internet searches, which was cited by 64 percent of the respondents (Figure 4). This suggests that companies use technology—although performing an Internet search on a computer is a low-level technology—to learn about new technologies. Other common ways that the surveyed businesses learn about technology are by interacting with other companies (57 percent), trade magazines and publications (55 percent), through industry associations (47 percent), and by attending meetings and conferences (42 percent). The input of workers—both existing workers (20 percent) and newly hired workers (17 percent)—plays a considerably less important role in learning about new technologies. The least-cited ways that the US

manufacturers covered by the survey learn about technology is through working with community

colleges (4 percent), on-site demonstrations (12 percent) and working with universities (14

percent).

Figure 4. Online and internet searches are the most common way that US manufacturers learn about technology.
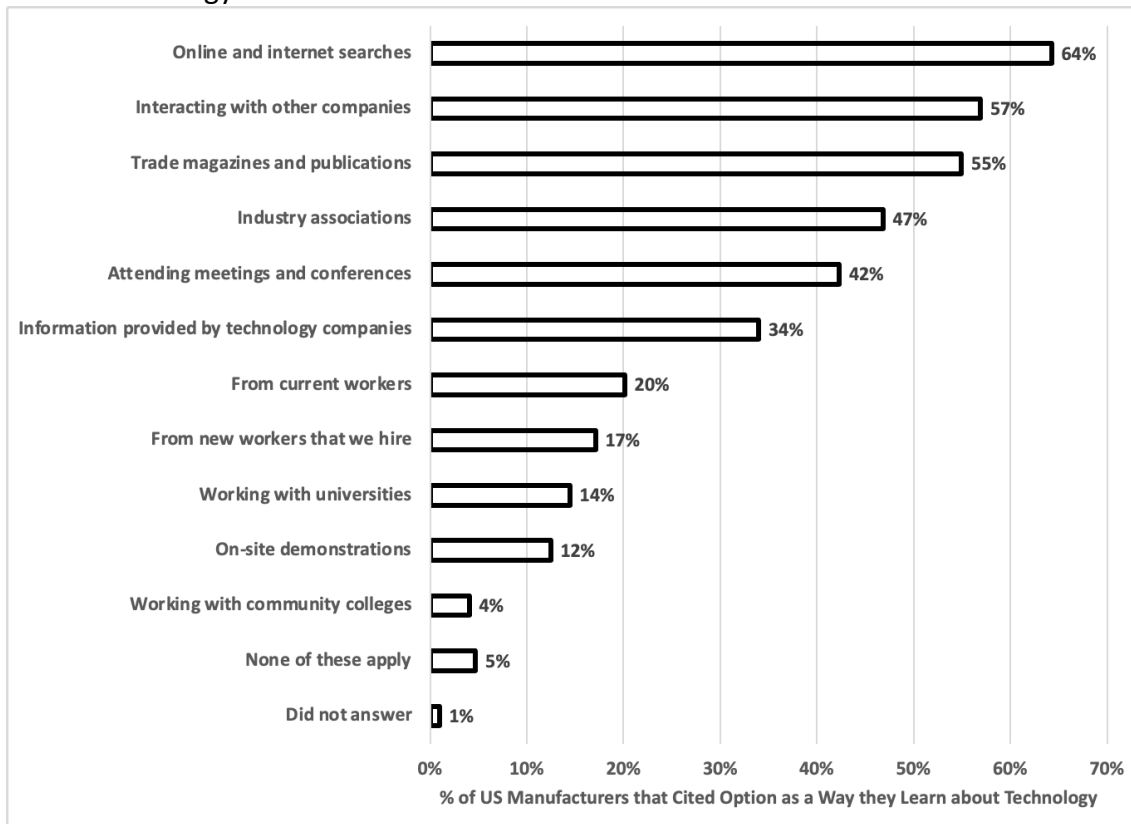
Notes. Data are from a 2023 survey of US manufacturers, n=268. Survey responses are weighted by business size.

A reasonably strong theme that emerges from Figure 4 is that US manufacturers are more

likely to learn about technology through their industry "peers" (e.g., interacting with other

companies, attending meetings, industry associations, trade magazines) than through their

interactions with universities and community colleges. Although fewer than 1 in 7 of the surveyed

US manufacturers indicated that they learn about technology by working with universities (14

percent) or community colleges (4 percent), 44 percent noted (on a different survey question) that they have collaborated with a university or community college.
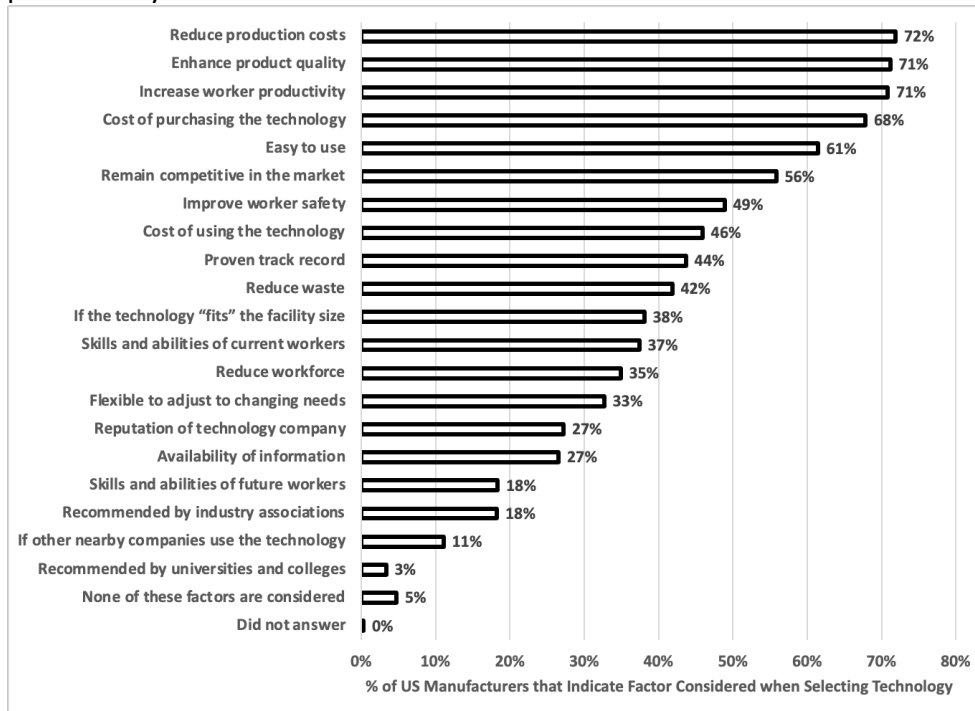
2.4   Factors Considered by US Manufacturers when Selecting Technologies

Figure 5 summarizes the factors that US manufacturers consider when selecting technologies to use.[12] The top 5 factors when selecting technologies are to reduce production costs (72 percent of the surveyed companies), enhance product quality (71 percent), increase worker productivity (71 percent), the cost of purchasing the technology (68 percent) and ease of use (61 percent). A strong theme that emerges at the top of Figure 5 is that the two most important broad drivers of technology selection are costs (the technology's ability to reduce the cost of production, and the costs of purchasing and using the technology) and the technology's ability to enhance product quality / increase worker productivity / remain competitive. Although these considerations were included as separate factors on the survey, they all relate to the way in which technology helps a company produce its goods and services. And the importance of these considerations when selecting technologies to use goes back to the original premise of technology's positive impacts on productivity and competitiveness.

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[12] The survey question asked respondents to indicate the factors that receive "at least moderate consideration" when selecting technologies.

Figure 5. US manufacturers select technologies to reduce costs, enhance quality and increase productivity.

Notes. Data are from a 2023 survey of US manufacturers, n=268. Survey responses are weighted by business size.

Although cited as a factor considered by 35 percent of the US manufacturers included in the survey, the ability to reduce a company's workforce is relatively far down the list of reasons why companies select a particular technology. Likewise, the skills and abilities of current workers (37 percent) and future hires (18 percent) were less frequently cited as factors considered when selecting a technology. Other factors that relatively fewer manufacturers consider when selecting technologies are the recommendation of universities and colleges (3 percent), if nearby companies are using the technology (11 percent), and the recommendation of industry associations (18 percent).

The relatively low percentage of US manufacturers that use the recommendation of universities and colleges when selecting a technology is consistent with the low percentage of

those that learn about technology by working with universities and community colleges. The relatively small percentages of US manufacturers that use the recommendation of an industry association or the use of a nearby company when selecting a technology to adopt, however, are somewhat at odds with how US manufacturers learn about technologies. Although 57 percent of the surveyed manufacturers learn about technologies by interacting with other companies and over 40 percent learn about technology via meetings and conferences and industry associations, the actual recommendation of industry associations and whether or not the technology is used by nearby companies hold considerably less weight when a US manufacturer selects a technology. Rather, the technology selection of US manufacturers is driven largely by cost considerations and how the technology will impact production.

In Figure 6, we see that the primary decision makers for selecting the technologies used by US manufacturers are on-site managers and owners (70 percent of the surveyed businesses), company executives (54 percent) and the companies' engineers and technicians (31 percent). On the other hand, it's rare that a university or college partner in a technology transfer (1 percent), industry association (2 percent) or other company involved in a technology transfer (3 percent) is a decision maker for selecting the technology used by a US manufacturer.

Figure 6. Managers and owners make technology decisions in almost three-quarters of US manufacturers.

Notes. Data are from a 2023 survey of US manufacturers, n=268. Survey responses are weighted by business size.

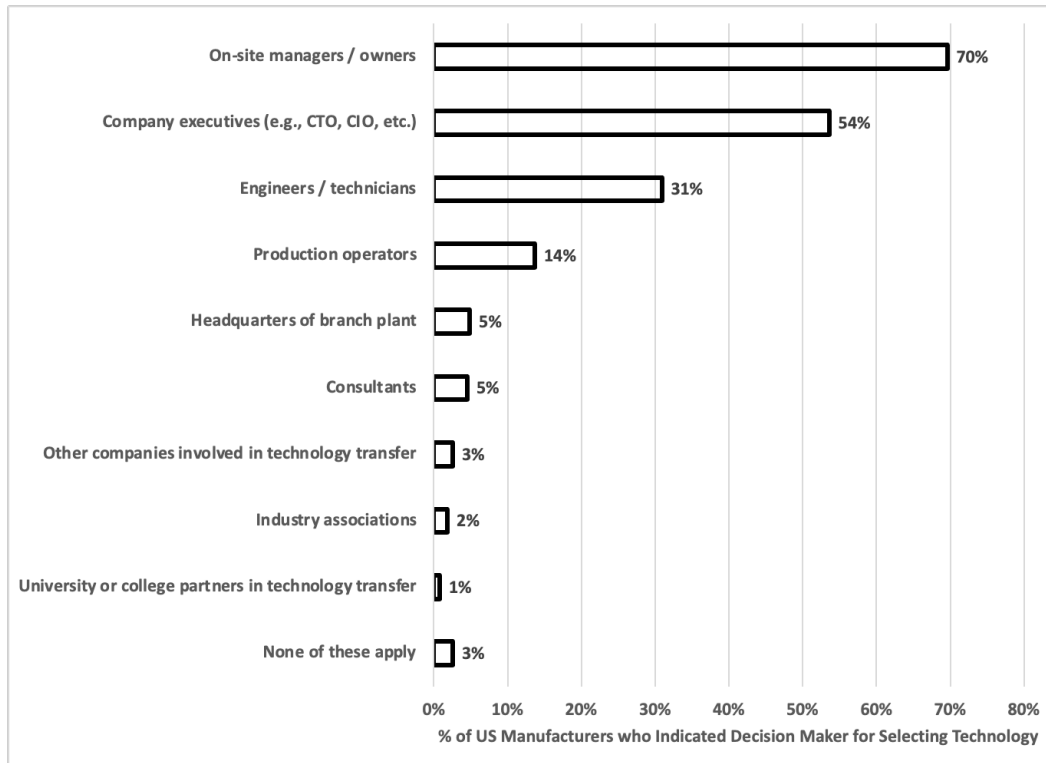3.   Future Adoption of AI or Machine Learning

The types of technologies used in manufacturing are constantly evolving and many of the applications available today were barely imaginable even 20 years ago. At the present time, artificial intelligence (AI) has been dubbed by some as "the next big thing" and AI is receiving a lot of interest in the media and the business world. The results of the survey, however, show relatively low levels of adoption, with 7 percent of the US manufacturers included in the survey indicating that they use AI or machine learning. Focusing on all types of businesses, a 2018 technology use survey conducted by the US Census Bureau found that 6.6 percent of all US firms use "some form of AI in the workplace" (Zolas et al. 2021).

To get a sense of the future of technology use—particularly as it applies to AI—the survey asked whether businesses were "considering the use of AI or machine learning in the future." This question was only asked of companies that are not currently using the technology. Survey results indicate that 22 percent of the US manufacturers that are not currently using AI or machine learning are considering its adoption in the future. This suggests that 28 percent of the manufacturers covered by the survey are either currently using AI / machine learning or are considering its use in the future.

4.   Summary and Key Insights

Technology is an important driver of productivity, which in turn impacts the competitiveness and vitality of companies and enhances the economic wellbeing of their workers and communities where they reside. A survey of US manufacturing businesses conducted at the end of 2023 reveals the following key insights related to technology use.

⇨ The technologies of computer-aided design, numerically or computer-controlled machines, and programmable controllers / programmable logic controllers are considerably more widespread in their adoption by US manufacturers than technologies such as virtual and augmented reality, robots, and AI / machine learning.

⇨ The most frequently cited barriers to technology use are the size and needs (e.g., "products don't require technology") of a company more so than concerns about various aspects of technology (e.g., fear of obsoletion). Put another way, US manufacturers are apt to use a technology if they need it and it's a good fit for their company.

⇨ When selecting technologies to use, US manufacturers consider the impacts of the technology on production and the business (e.g., enhance product quality, increase worker productivity) and costs (reduce production costs, costs of purchasing the technology) more so than the skills of workers and use or recommendations of others. In other words, the most important factors when selecting technologies are the very same ways in which companies benefit from technology use.

⇨ Workforce issues are somewhat important to the technology use and decisions of US manufacturers, but they are often overshadowed by other factors. For example, a lack of skills of current and future workers is more frequently cited than, say, reliability or obsoletion concerns as a barrier to technology use, yet the two most cited barriers are business size and that the products made by the company do not require technology. Likewise, about 1 in 5 of the US manufacturers covered by the survey learn about technology from current and new workers, yet US manufacturing businesses are considerably more likely to learn about technologies through interactions with other companies and industry associations. Finally, the skills and abilities of current and future workers are pretty far down the list of factors that US manufacturers consider when selecting a technology. Taken together, the survey results show that workforce issues matter—perhaps more so as a barrier to technology use—but workforce issues are never "the most important thing."

⇨ When it comes to matters related to technology, US manufacturers are more internally focused (or impacted by other companies) than following the lead of universities and community colleges. US manufacturers are considerably more likely to learn about

technology through an online search or interactions with other companies than through working with universities and community colleges, and very few US manufacturers indicate that they consider the recommendations of universities and colleges when selecting a technology (and almost no manufacturers indicated that university or college partners in technology transfer are decision makers for selecting technology). These findings, combined with the result that 40 percent of the surveyed US manufacturers have collaborated with a university or community college, suggest that the business and higher education partnerships are more based on "two-way" collaboration as opposed to universities and community colleges dictating the technologies used by manufacturers.

These key insights and the analysis presented in this paper provide a detailed picture of the technologies used by US manufacturers, the barriers to use, the ways that businesses learn about technology, and the factors considered when adopting new technologies. Future research will expand on these insights with additional in-depth analysis of the impacts of technology on businesses and their surrounding regions.

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Appendix: Survey Data

The information presented in this paper is based on the analysis of survey data collected from 268 US manufacturing businesses during the end of 2023. The survey was administered online via Qualtrics and the companies that were asked to complete the survey were identified from an email list of US manufacturers purchased from Data Axle. Overall, we sent email invitations (and reminders to nonrespondents) to 75,000 companies and 8,850 of these invitations were "undeliverable" due to invalid email addresses. In addition, it's likely that an unknown number of email invitations to complete the survey were flagged by the individuals' email server as spam messages and were never received by the intended recipient. Of the 66,150 surveys that were potentially received by the manufacturing companies (i.e., 75,000 original messages minus the 8,850 that were undeliverable), a total of 1,367 surveys were started by companies. This gives a response rate of 2.1 percent.

This low response rate is likely explained by a general disinterest in completing an unsolicited survey but is also influenced by the fact that an unknown number of email invitations did not make it into the inbox of the intended recipients (i.e., flagged as "spam") and an unknown number of invitations to complete the survey were received by companies that would not self-identify as manufacturers. Related to this second point, the email list used to contact companies covers the manufacturing SIC code of 20-39.[13] Some of the companies classified in the email list as "manufacturers" could be, for example, small service businesses that offer printing services (e.g., might be classified as SIC 27), a retail bakery (classified as SIC 20) or a one person "business"

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[13] Data Axle uses SIC codes to classify businesses by industry.

that makes craft products (e.g., a person who makes wooded craft items could be classified as a wood product manufacturer, SIC 24).

From the 1,367 surveys that were started by companies, we arrive at our sample of 268 companies after removing observations with missing values for the number of workers employed by the business. The reason we removed these companies is because the survey responses are weighted by employment size. In particular, we weighted the observations using nine employment size categories (i.e., Establishments with less than 5 employees, Establishments with 5 to 9 employees, …, Establishments with 1,000 employees or more) with manufacturing establishment counts from 2021 County Business Patterns data. Relative to the 283,015 manufacturing establishments covered in the 2021 County Business Patterns data, the 268 companies in our sample account for 1 out of 1,056 US manufacturing businesses.