Impacts of Automation on Pima County Employment

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Pima County Workforce Investment Board

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Executive Summary

We are in the midst of a new industrial revolution. These are never comfortable, but they do bring about huge increases in economic wealth. The current industrial revolution is being driven by advancements in artificial intelligence, robotics, genetic engineering, and big data (Schwab (2017), Brynjolfsson and McAfee (2014)). One sector of the economy sure to be impacted by automation is the labor market. Millions of jobs worldwide will be displaced by automation in coming decades. However, it is possible that millions more will be created, as productivity gains raise income. Rising income, in turn, generates increased demand for labor across all industries and occupations. Further, new technologies will create new occupations and industries, which will generate new jobs. If that happens, it means that the current industrial revolution will be like many of those we have experienced in the past. The primary impact will be reallocations of workers across occupations, with new jobs requiring more and/or different skills than the jobs being eliminated. This will place the education system at the center of the adjustment mechanism, smoothing the transition of workers from one occupation/industry to another, as well as producing new graduates with the right skills to work increasingly with robots and artificial intelligences.

This report reviews the economic literature on the likely workforce impacts of automation and applies the results of one prominent paper to Pima County. Overall, the results suggest that the coming wave of automation will have significant impacts on labor markets globally, nationally, and locally. While there is good reason to expect that net job gains will continue in the aggregate, there is no doubt that significant labor market disruptions are coming. Indeed, the estimates in this report suggest that there may be 154,458 jobs at risk of automation in Pima County during the next decade or so. That translates into 42.4% of all local jobs in 2017, slightly below the national share of 45.7%. Further, the results also suggest that job displacement is likely to be concentrated on low wage occupations requiring less educational attainment.

Across occupations in Pima County, food preparation and serving; farming, fishing, and forestry; sales; building and ground maintenance; production; office support; and transportation and material moving have the highest risk of automation. At the other end of the spectrum, community and social services; management; architecture; education, training, and library; healthcare practitioners; computer and math; artists; and life, physical and social science occupations have relatively low risks of automation.

Industries with the highest probability of computerization include leisure and hospitality; trade, transportation, and utilities; and natural resources and mining. In contrast, education and health services; information, and government have relatively low risks of automation.

McKinsey Global Institute (MGI) (May 2018) estimate that the following skill sets will be in more demand in coming decades: advanced IT skills and programming, basic digital skills, entrepreneurship and initiative taking, leadership and managing others, creativity; and complex information processing and interpretation. Skills likely to be less demand in coming decades

include basic data input and processing; basic literacy, numeracy, and communication; general equipment operation and navigation; inspecting and monitoring.

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Introduction

Will machines take all of our jobs? Surprisingly, that is an old question. It has been asked by 16th century English knitters, by agricultural workers in the U.S. in the 20th century, by automobile industry workers worldwide during the past few decades, by bank tellers, bookkeepers, cashiers, food preparers and servers, and myriad others today.

So far, and on net for the aggregate economy, the answer has been an emphatic no. There are many, many more jobs in the U.S. and worldwide today than there were 20, 40, 60, 100, or 400 years ago. Nonetheless, the introduction of machines into the workforce has created huge labor market dislocations. It has eliminated jobs in some occupations and industries (blacksmiths) and created jobs in others (machine repair and maintenance). It has also spurred the creation of many new occupations (webmaster). In other words, we have increasingly worked with machines, not for them. This trend is likely to continue.

This report reviews the economic literature on the likely workforce impacts of automation and applies the results of one prominent paper to Pima County. Overall, the results suggest that the coming wave of automation will have significant impacts on labor markets globally, nationally, and locally. While there is good reason to expect that net job gains will continue, in the aggregate, there is no doubt that significant labor market disruptions are coming. Indeed, the estimates in this report suggest that there may be 154,458 jobs at risk of automation in Pima County during the next decade or so. That translates into 42.4% of all local jobs in 2017, slightly below the national share of 45.7%.

Keep in mind, however, that this does not necessarily imply net jobs losses for Pima County (or nationally). Automation will displace workers from some jobs/occupations. It will also create jobs in other occupations, although those jobs will likely require more and different skills.

In particular, McKinsey Global Institute (MGI) (May 2018) estimate that the following skill sets will be in more demand in coming decades: advanced IT skills and programming; basic digital skills; entrepreneurship and initiative taking; leadership and managing others; creativity; and complex information processing and interpretation. Skills likely to be less demand in coming decades include basic data input and processing; basic literacy, numeracy, and communication; general equipment operation and navigation; inspecting and monitoring.

In the next section we survey the key economic research on the labor market impacts of automation. Then we turn to adapting the results of one prominent paper to Pima County in order to gauge local employment impacts. We conclude the paper with a summary of results and cautions for their interpretation.

Automation and Employment

Judging the impact of automation on the workplace is extremely difficult. Understanding the current capabilities of intelligent machines and predicting their future development is challenging on its own. Analyzing the impact of automation on the workplace further requires that we know how humans will choose to deploy and use intelligent machines to increase productivity. Increased use of automation in the workplace is likely but not inevitable. We can and sometimes have chosen to forego their use, at least for a time. Increased automation will certainly disrupt the labor market, but no one knows for certain if the net results will be more, the same, or fewer jobs in aggregate.

As is common on this subject, there are differences of opinion and empirical result. One strand of the economic literature focuses on the potential for automation to replace human labor in the future. Another strand seeks to understand the past impacts of automation on net employment, either by occupation or in the aggregate.

To date, the results analyzing the past impacts on aggregate net employment are mixed. Autor (2015), Autor and Dorn (2013), Autor, Dorn, and Hanson (2015), and Autor and Salmons (2018) suggest that the net impact of automation in the recent past has been neutral or positive for jobs in aggregate. Some occupations have suffered, primarily so called middle-skill jobs, during the past 30 years. These included many blue-collar, clerical, and sales occupations, which entailed routine (easily codifiable) tasks. Occupations that thrived were low-skill service occupations and high-skill professional occupations, which entailed primarily non-routine tasks and personal interaction.

MGI also come to a hopeful conclusion through their micro-to-macro forecast approach. Summary results made publicly available suggest that automation will generate net job gains globally. While MGI (June 2018, May 2018, December 2017, January 2017) estimate in their middle scenario that automation will displace 15.0% of the global workforce during the 2016-2030 period. Their pessimistic scenario suggests that automation could displace 30.0% of the global workforce, while an optimistic scenario shows nearly zero job loss to automation. However, these technology-driven job losses are more than made up for by job gains in other sectors/occupations that are driven by overall economic growth. Thus, future automation creates reallocations of labor across industries and occupations.

This strand of the literature is optimistic about the future of humans in the workplace, as long as the education system can be retooled to produce graduates that are expert in creating and working with intelligent machines and artificial intelligences, as well as graduates that are highly skilled in problem solving, facilitating person to person interactions, and flexibly using judgement and common sense. This strand also assumes that the future will be like the past, in the sense that productivity enhancements made possible by automation will increase the aggregate standard of living sufficiently to generate additional demand for labor to offset the direct automation job loss.

In contrast, Acemoglu and Restrepo (March 2017) come to a less optimistic conclusion, at least with respect to the impact of industrial robots during the 1990 to 2007 period. An industrial

robot is a fully autonomous machine that does not require a human operator and that can be programmed to accomplish multiple tasks. Their analysis allows for industrial robots to have both a job-displacing impact and a job creating impact. At the local labor market level, their results suggest that an increase in the exposure to robots (one additional robot per 1,000 workers) reduces local employment by as much as six jobs and as little as three jobs, depending on model specification. In aggregate, they estimate that robots have replaced between 360,000 and 670,000 jobs nationwide. The impacts tended to be most pronounced in manufacturing and industries most exposed to robots, such as routine manual, blue collar assembly, and related occupations. The estimated impacts are also larger for workers with less than a college education. One important caveat in this work is the lack of an offsetting technological response (creation of new labor-intensive tasks) (Acemoglu and Restrepo (June 2017)).

An alternative approach has been to analyze the potential for automation to advance and create labor market impacts across occupations. The most prominent study in this strand is Frey and Osborne (2013). They envision a future in which machine learning (coupled with big data) and mobile robotics allows automation to impact non-routine cognitive jobs previously thought to be impervious. In particular, they see automation moving rapidly forward in health care (especially diagnostic services and patient monitoring), financial activities (automated analysis and trading), professional and business services (legal research, call centers, surveillance), and education (massive online courses that predict student performance and prospects for further study).

The authors also envision a world in which mobile robotics allow industrial and service robots to compete effectively with human labor. This includes surgical robots, self-driving vehicles, robot harvesters and produce pickers, as well as industrial solutions employing dexterous robots that can take over complex manual tasks in manufacturing, packing, construction, and maintenance.

In essence, Frey and Osborne (2013) focus on engineering bottlenecks in order to separate occupations that are more or less susceptible to computerization. They isolate three of these bottlenecks: perception and manipulation tasks, creative intelligence tasks, and social intelligence tasks. Occupations which require human-like skills in these tasks are considered to be at lower risk of automation than occupations which require low levels.

Perception and manipulation tasks require workers to identify objects in complicated fields of view. These commonly happen in unstructured environments that feature many uneven surfaces and objects, such as the home. In contrast, examples of structured work environments include supermarkets, factories, and warehouses, which are often optimized for wheeled vehicles.

Creative intelligence tasks require the creation of new things or ideas that fit in old or new contexts. These include new concepts, like poems, writings, films, theories, recipes, and jokes, as well as new objects, such as paintings, machinery, clothing, etc.

Social intelligence tasks include negotiation, persuasion, and care, among others where emotional connections are likely to matter.

Thus, in their view, the probability that an occupation will be automated in the next few decades is a declining function of the importance of the three task groups for that occupation. The more important these three task groups are, the lower the probability of automation.

The authors implement their ideas by combining machine learning with big data. In this case, they employ an application of neural networks to data on 702 U.S. occupations (in 2010) with detailed descriptions of the skills and abilities required for those occupations found in O*NET. In particular they focus on the following O*NET variables: finger dexterity, manual dexterity, cramped workspace, and awkward positions for perception and manipulation; originality and fine arts for creative intelligence; social perceptiveness, negotiation, persuasion, and assisting and caring for others for social intelligence. Occupations which score higher on these variables (require more of these skills) are assigned lower probabilities of automation.

Their empirical results (summarized in more detail and adjusted for Pima County occupation/industry mix in the next section) suggest that in 2010 roughly 47.0% of U.S. jobs were at high risk of automation within the next two decades or so. That is a big number. It is important to remember, however, that this analysis focused only on the substitution (job reducing) effect of automation. It is just one side of the coin. The other side of the coin is the growth and welfare improving impact of automation. Thus, even though automation is likely to destroy a large number of jobs (just has it has throughout history), it is also likely to create jobs in other occupations/industries and/or create new occupations/industries altogether. Thus, the empirical estimates presented here tell us about the number of jobs that might need to be created to offset the substitution effect of automation.

Their results also suggest the occupations that are most likely to be adversely affected by automation are low wage and require relatively low levels of educational attainment. Thus, in order to successfully ride the wave of automation that may be coming, it will be increasingly necessary to work with, understand, repair, and maintain artificial intelligences and robots.

Pima County Employment and Automation

Research suggests that the impacts of automation on employment will differ significantly across occupations and worker skill sets. As summarized in the previous section, Frey and Osborne (2013) offer a novel approach to measuring the share of U.S. jobs (by detailed occupation) that will be computerisable in the next decade or two. They conclude that the share of jobs across 702 occupations that are likely to be affected by automation was about 47.0% in 2010. Occupations that are likely to be most affected are those requiring less education and paying lower wages.

Across 811 U.S. occupations for which data for 2017 exists, 45.8% of U.S. jobs are at high risk of computerization (defined as an employment in an occupation with a probability over 0.70), as Exhibit 1 shows. The middle range, with detailed occupations assigned a probability of 0.31-0.70, accounted for 23.0% of employment in 2017, while low risk occupations, with probabilities of 0.0 to 0.30, accounted for 31.2% of jobs.[1]

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[1] This requires the estimation of 109 probabilities for occupations not covered in Frey and Osborne (2013). These are created by the author, using judgement based on probabilities for similar occupations.

Exhibit 1: U.S. Employment Shares In 2017 By Probability Of Computerisation
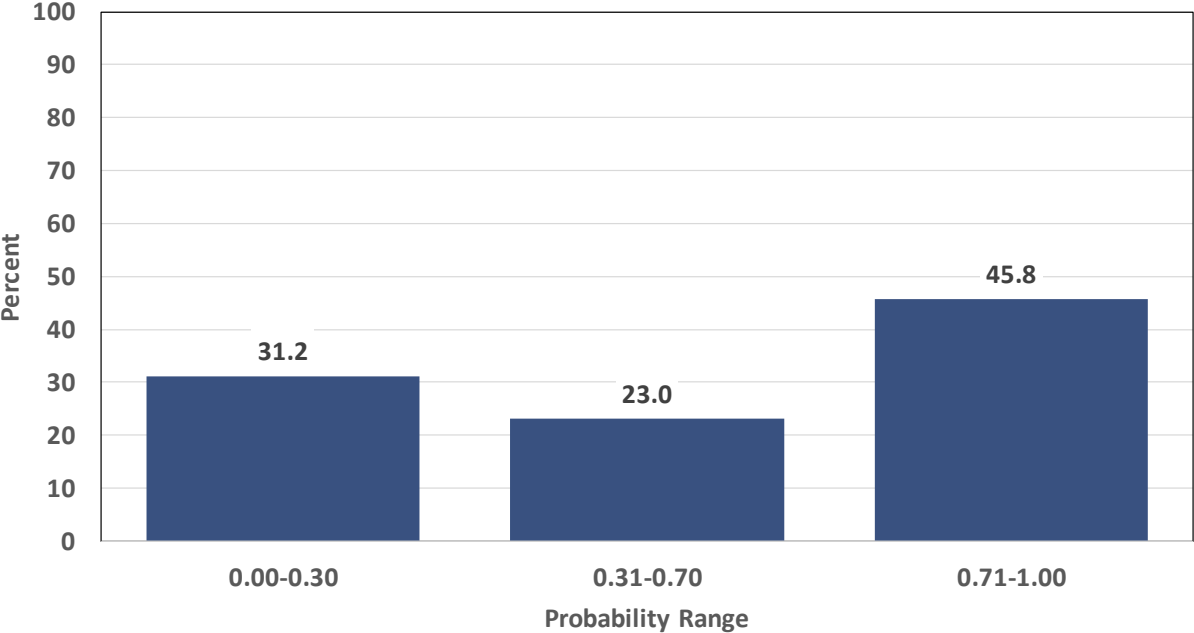

Exhibit 2 breaks out U.S. employment shares in more detail. Note that the distribution is heavily weighted toward very high and very low risk occupations. Indeed, 28.7% of jobs are in the very high probability group at over 0.9. On the other end of the distribution, 21.7% of jobs are assigned a probability of being computerized of 0.1 or less.

For the "all other" categories for major occupation groups, probabilities are assigned as the average for the major group.

Exhibit 2: U.S. Employment Shares In 2017 By Detailed Probability Of Computerisation
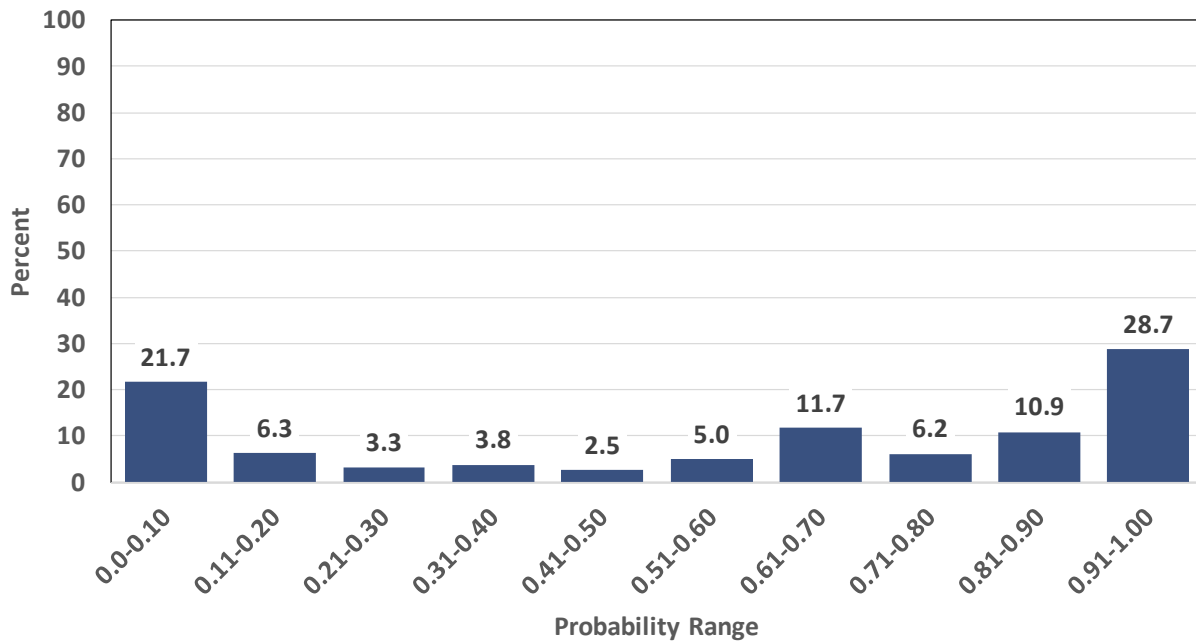
The occupations assigned the highest probability of computerization (at 0.99) include photographic process workers; watch repairers; data entry keyers; cargo and freight agents; new account clerks; telemarketers; library technicians; title examiners; and tax preparers. Occupations assigned the lowest probability (at less than 0.004) of automation include legislators; recreational therapists; emergency managers; first line supervisors of mechanics; mental health workers; audiologists; healthcare social workers; occupational therapists; prosthetists; oral surgeons; lodging managers; and dieticians.

Exhibit 3 summarizes the probability of computerization by median wage in 2017.[2] Note that median wages were highest for detailed occupations that have low probabilities of automation (at $65,970, excluding fringe benefits), while wages were lowest for occupations that have high probabilities of automation (at $36,990).

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[2] Reported medians are the median of occupational median wages.

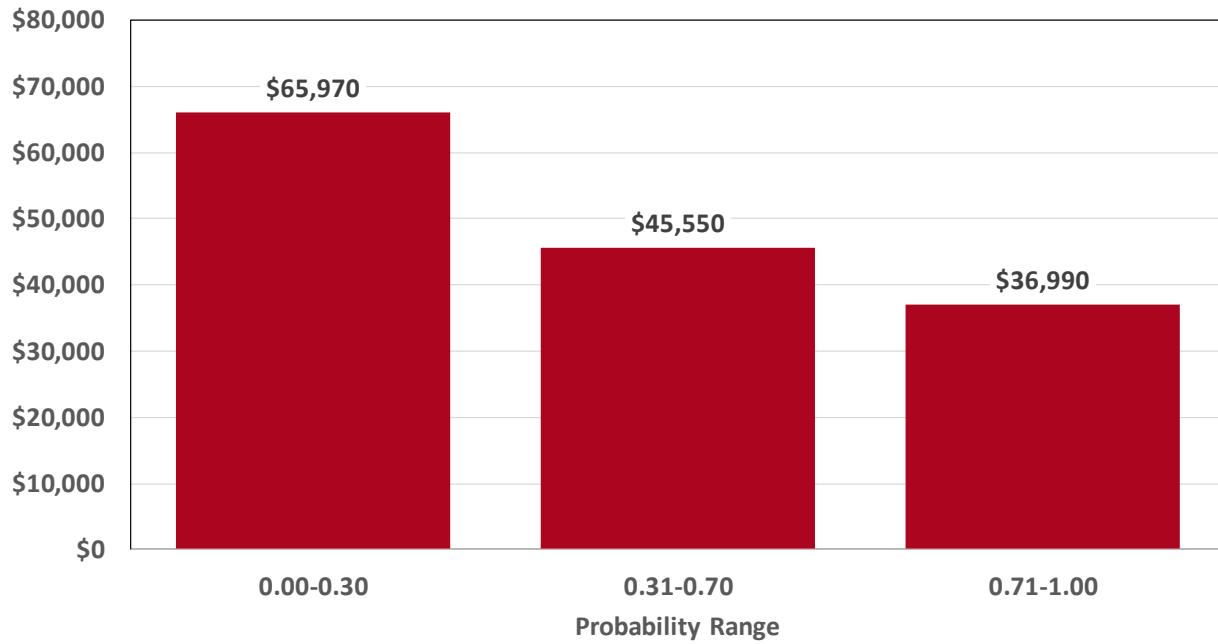**Exhibit 3: Median Occupational Wages In 2017 By Probability Of Computerisation**

Exhibit 4 gives a more detailed breakdown. Again, median wages were much higher for the low probability occupations (0.0-0.10) at $69,590. Wages were lowest for the high probability occupations (0.91-1.00) at $34,600.

**Exhibit 4: Median Occupational Wages In 2017 By Probability Of Computerisation**
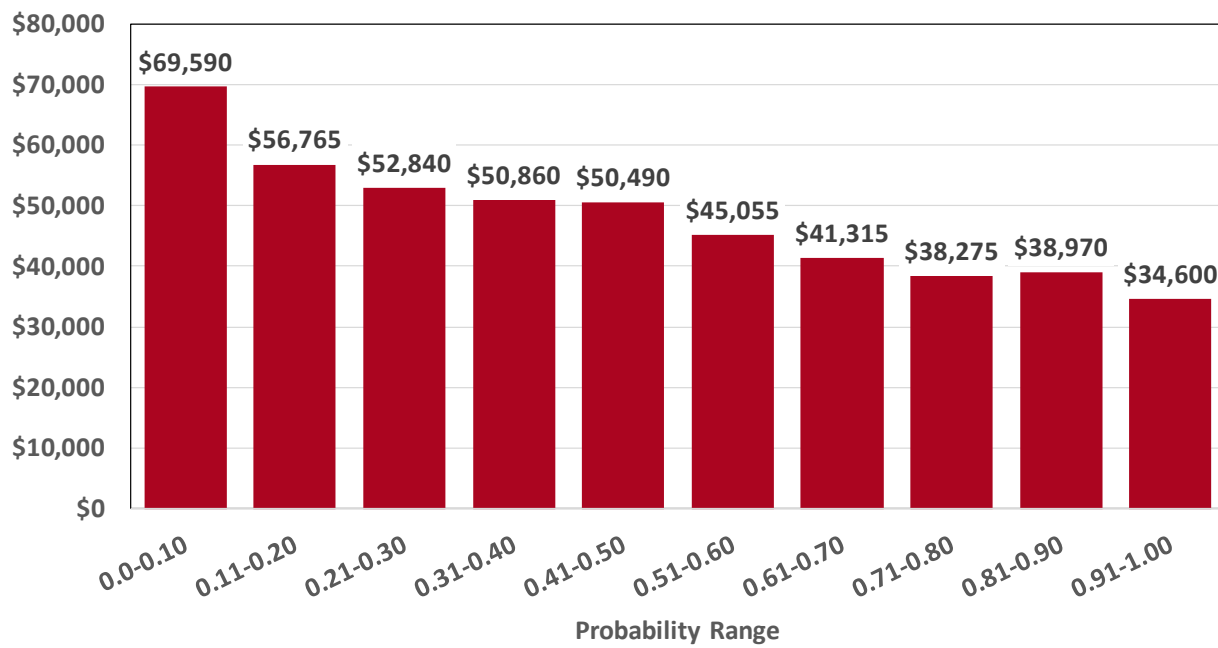
We can aggregate probabilities for the 811 detailed occupations into 22 major occupations, using employment shares as weights. The results are summarized in Exhibit 5. Note that the major occupations with the lowest probabilities of computerization include community and social services; management; education, training, and library; healthcare practitioners; artists; and architects. Each of these major has a less than 20% risk of automation. This reflects the high value placed on social and creative intelligence in these occupations.

Occupations on the other end of the spectrum include food preparation and serving; farm, fishery, and forestry; office support; sales; production; and transportation and material moving. Each of these major groups has at least a 75% chance of automation.

Exhibit 5: Probability Of Computerisation By U.S. Major Occupation In 2017
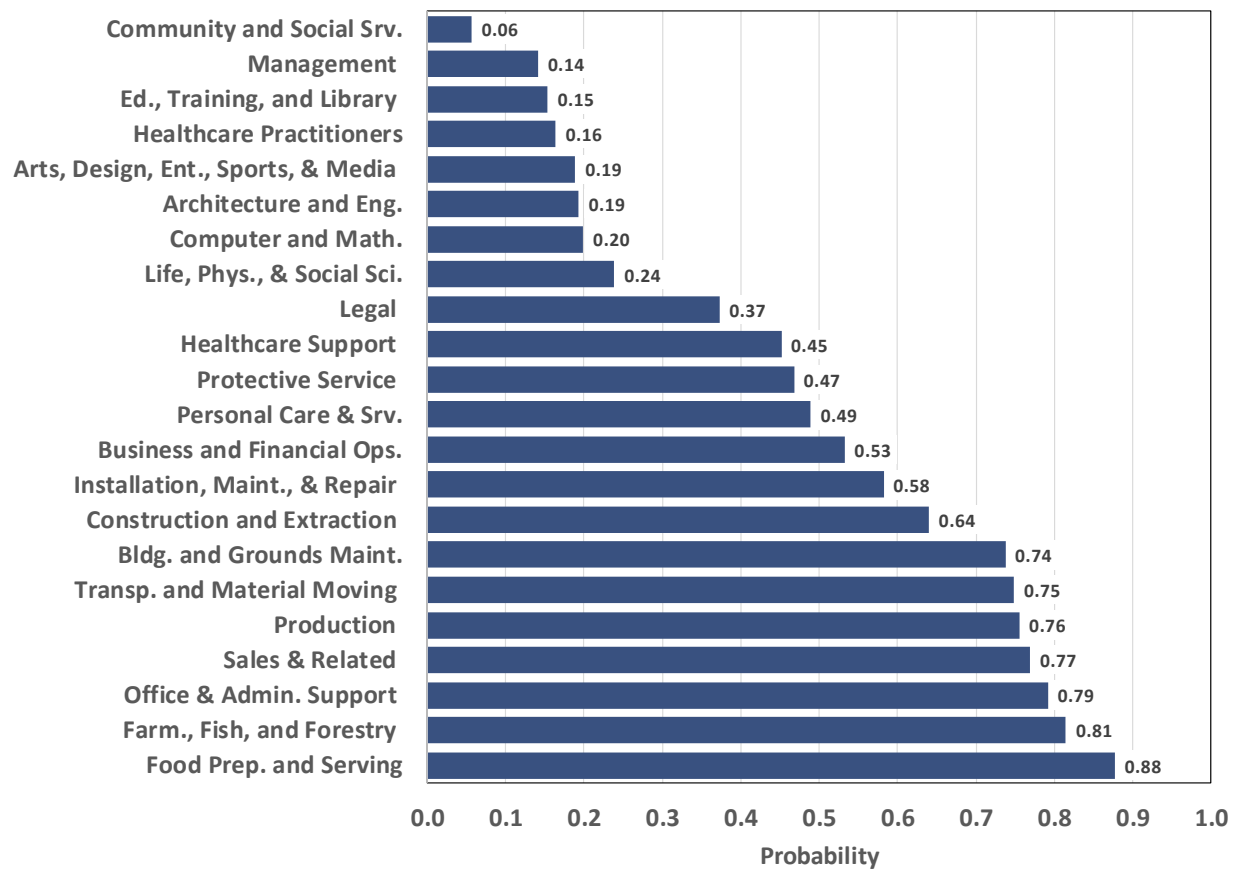
Each year, the BLS publishes a U.S. industry/occupation matrix, which estimates occupational employment within each NAICS (North American Industrial Classification System) industry. This allows us to translate the probabilities of computerization by occupation into probabilities of computerization by industry, using occupations shares as weights. Exhibit 6 summarizes the results for the U.S. Note that the industries with the highest probabilities of computerization are accommodation and food services; agriculture, forestry, and fishing; transportation and warehousing; and retail trade. Each of these industries has a probability of computerization of over 70.0%. In contrast, educational services; health care and social assistance; professional,

scientific, and technical services; information; management; and government each have a probability of computerization of less than 50.0%.

Exhibit 6: U.S. Probability Of Computerisation By NAICS Industry In 2017
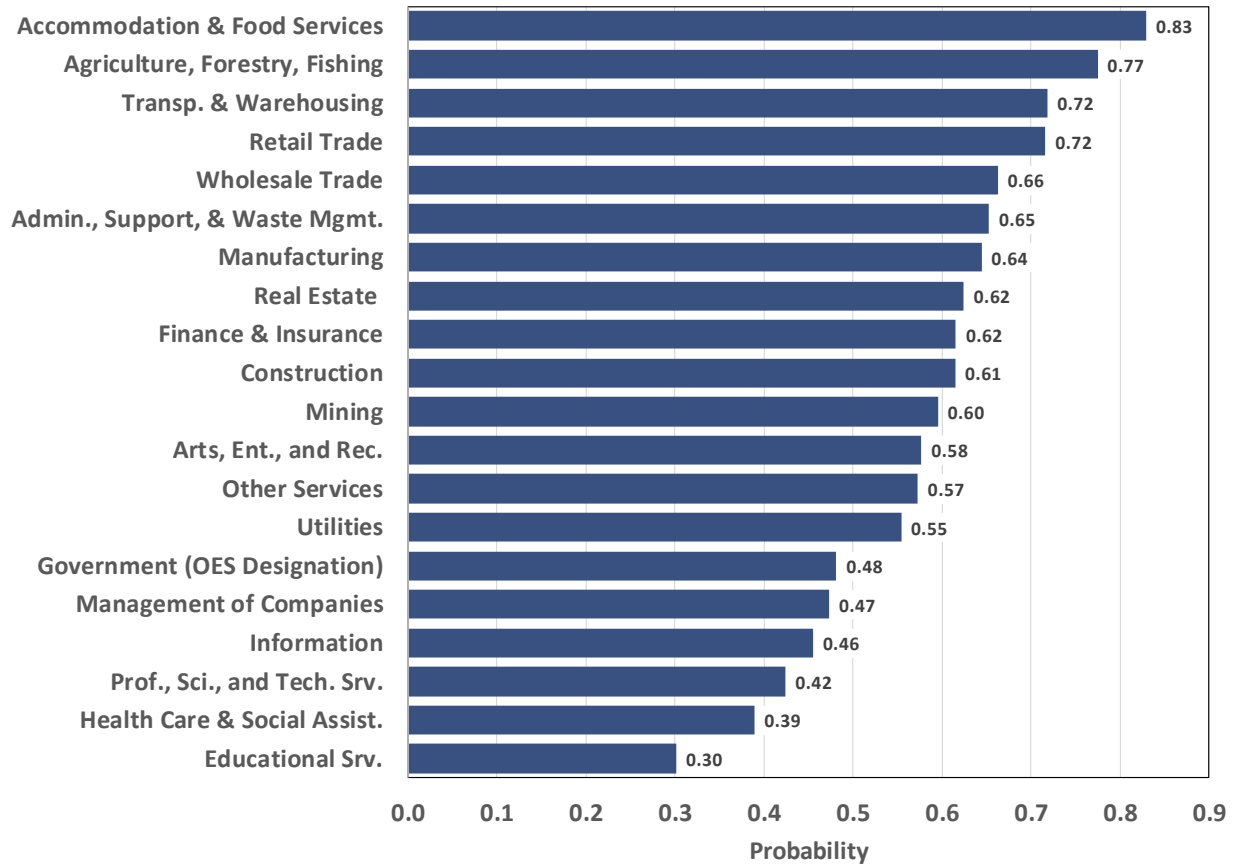
Using data on the industry and occupational mix for Pima County, we can recalibrate the results above to better reflect local conditions.[3] As Exhibit 7 shows, 42.4% of jobs in Pima County were at high risk of automation in 2017. That was below the national share at 45.7%, for comparable occupations.[4] Pima County's share of jobs in the low risk category in 2017 was 33.4%, just above the national rate of 31.2%.

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[3] Hong and Shell (2018) adapt the Frey and Osborne (2013) national estimates for the Federal Reserve Bank of St. Louis District and find that 60.0% of jobs there could face automation in coming decades. Similarly, Kinder (2018) adapts the same data to conclude that 35.0% of Phoenix MSA jobs could face automation in coming decades.

[4] U.S. results reported here differ from those above because not all U.S. occupations are reported for Pima County.

Exhibit 7: Pima County And U.S. Employment Shares In 2017 By Probability Of Computerisation
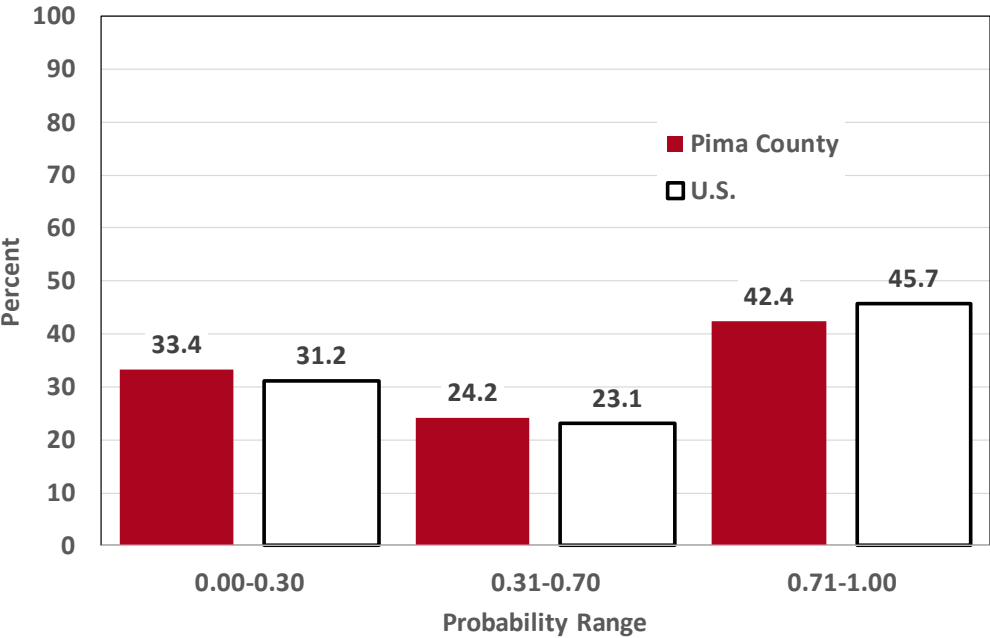

Exhibit 8 provides a more detailed breakdown by probability range. In 2017, 27.0% of Pima County jobs were in the highest probability range (0.91-1.00), compared to 29.0% for the nation. For, Pima County, that translated into 154,458 jobs. In contrast, 23.1% of Pima County jobs were in the lowest range (0.0-0.10), compared to 21.5% for the nation. Overall, Pima County's employment mix was a bit less exposed to automation than the nation.

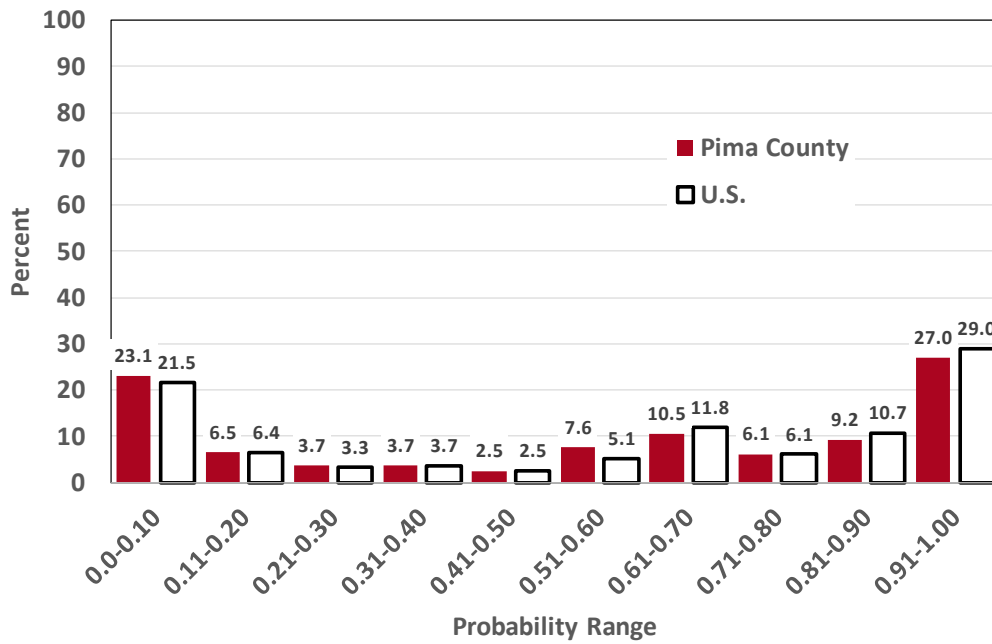**Exhibit 8: Pima County And U.S. Employment Shares In 2017 By Detailed Probability Of Computerisation**

Exhibit 9 shows median wages by probability of automation for Pima County and the nation. Pima County wages are much higher for the low probability group, at $55,830, than for the high probability group, at $33,435. The pattern is similar for the U.S. Note that median wages in Pima County are below the U.S. for each probability group.

Exhibit 9: Median Occupational Wages In 2017 By Probability Of Computerisation
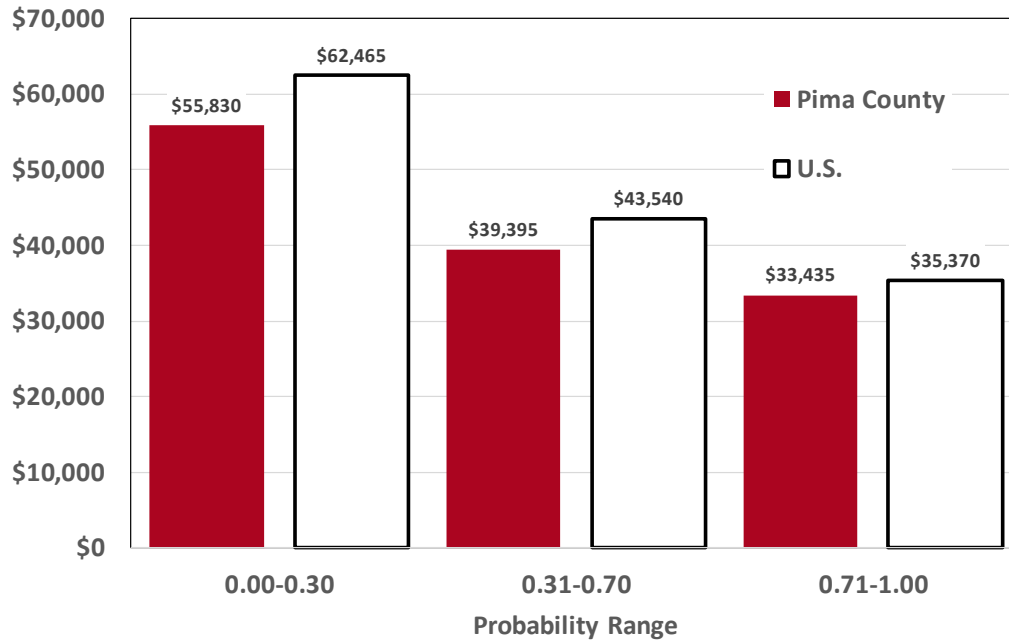

Exhibit 10 breaks median wages out by detailed probability range. Again, median occupational wages tend to fall as the probability of computerisation rises. Indeed, Pima County median wages for the lowest probability group (0.0-0.10) were $57,585, compared to $31,980 for the highest probability group (0.91-1.00) Note again that Pima County wages are below the nation for most groups.

Exhibit 10: Median Occupational Wages In 2017 By Detailed Probability Of Computerisation
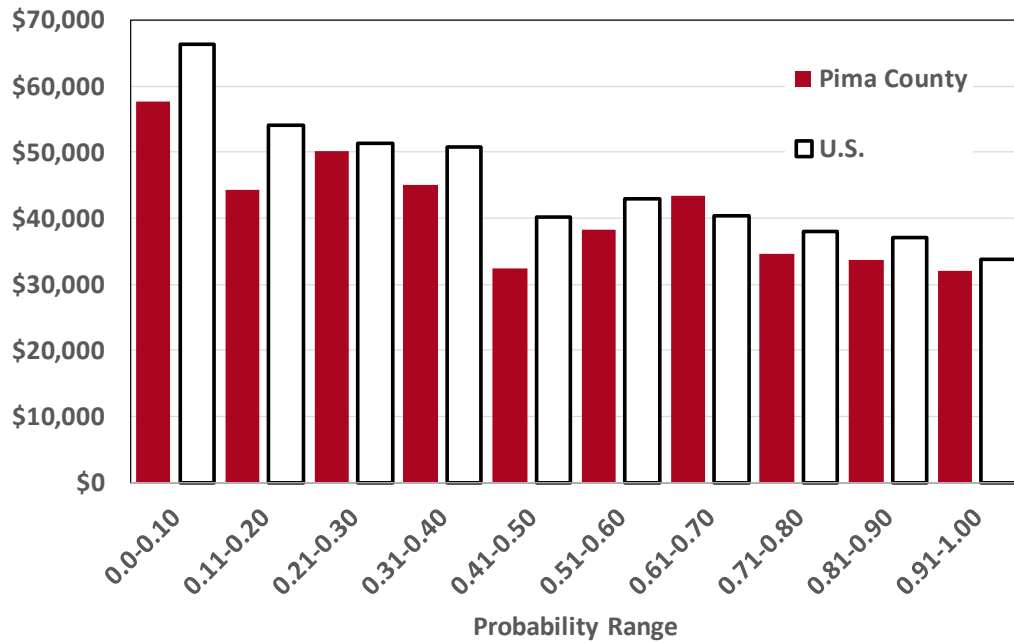

Exhibit 11 shows the probabilities of computerization for Pima County (and the U.S.) by major occupation group. Similar to the nation, food preparation and serving; farming, fishing, and forestry; sales; building and ground maintenance; production; office support; and transportation and material moving had the highest risk of automation. The probability of computerization for each of these occupation groups was above 0.75.

At the other end of the spectrum, community and social services; management; architecture; education, training, and library; healthcare practitioners; computer and math; artists; and life, physical and social science occupations had relatively low risks of automation. The probability of computerization for each of these groups was below 0.3. This reflects the high value placed on social and creative intelligence in these occupations.

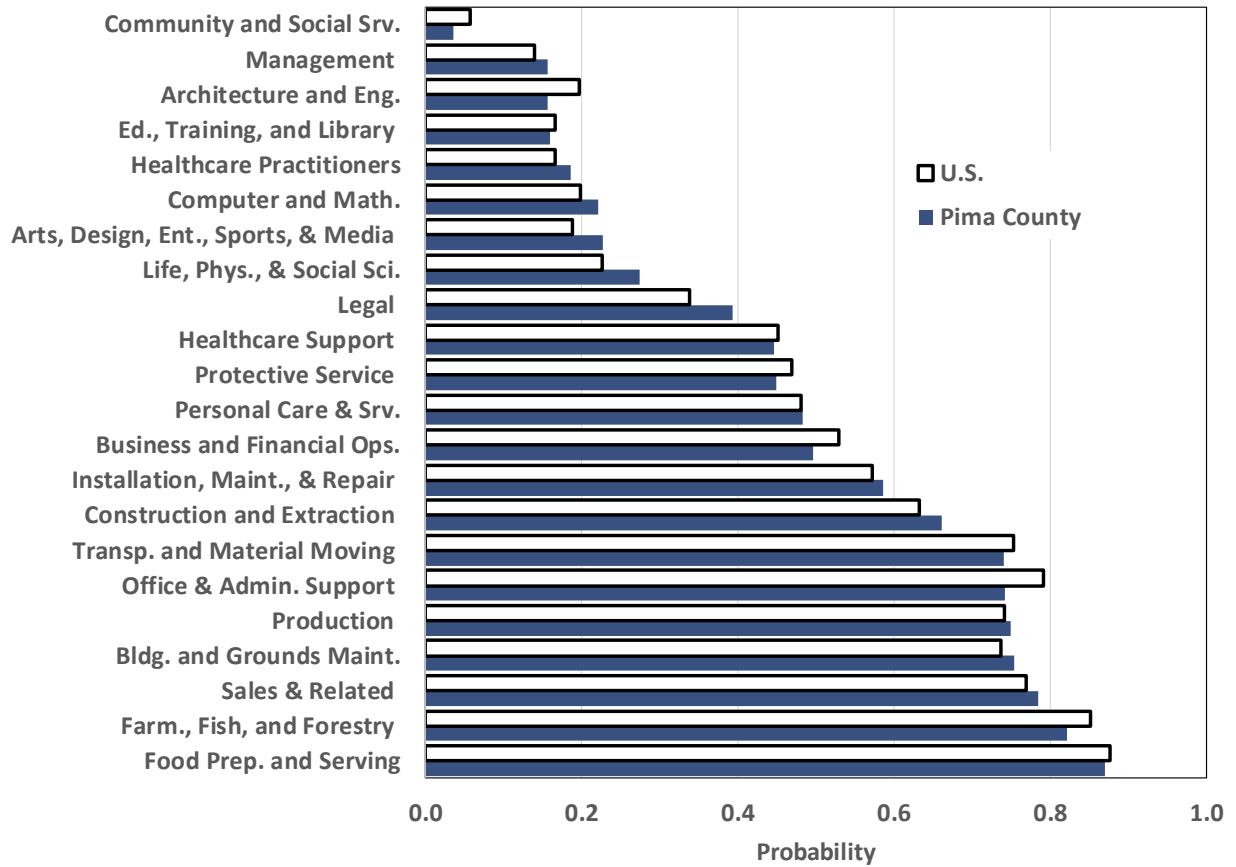**Exhibit 11: Probability Of Computerisation By Major Occupation In 2017 For Pima County And The U.S.**

Exhibit 12 shows the probability of computerization for Pima County (and the U.S.) by NAICS industry. Note that the industries with the highest probability of computerization included leisure and hospitality; trade, transportation, and utilities; and natural resources and mining. Each of these industries had a risk of automation above 0.60. In contrast, education and health services, information, and government had relatively low risks of automation, at below 0.50.

Exhibit 12: Probability Of Computerisation By NAICS Industry In 2017 For Pima County And The U.S.
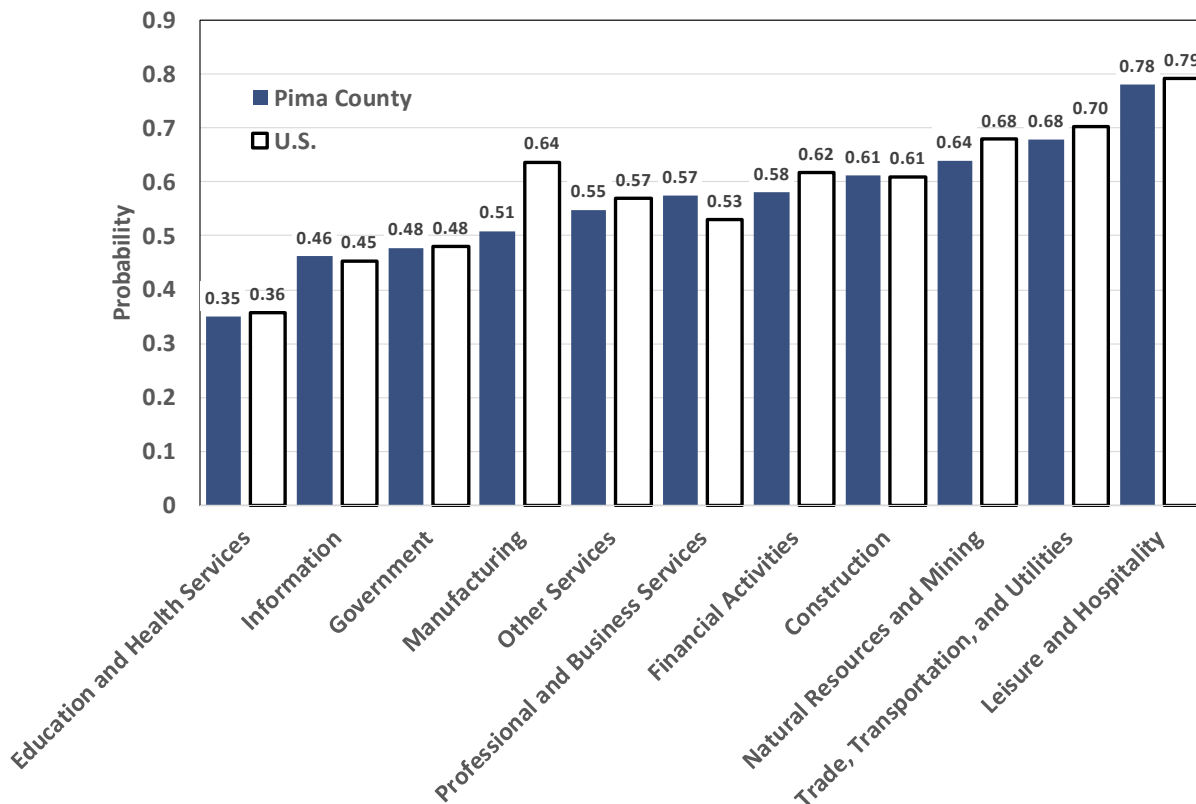
Conclusion

This study has addressed the potential impacts of automation on Pima County employment. Using national estimates from Frey and Osborne (2013), the results suggested that 154,458 jobs in Pima County are at high risk of being replaced by automation in the next decade or so. That translates into 42.4% of Pima County employment, slightly less than the national average of 45.7%.

The characteristics of jobs that are less likely to be automated in the next decade or so include a high degree of precise perception and manipulation, social intelligence, and creative intelligence. Occupations that tend to require high levels of these characteristics include community and social services; management; architecture; education, training, and library; healthcare practitioners; computer and math; artists; and life, physical and social science occupations.

Occupations that score low on these characteristics include food preparation and serving; farming, fishing, and forestry; sales; building and ground maintenance; production; office support; and transportation and material moving.

It is important to remember that these estimates only consider the job-eliminating effects of automation. There are likely to be powerful positive impacts on job creation as well. Rising productivity will increase income, which will spur additional demand for labor across all industries and occupations. Further, technological progress will create new occupations and industries, which will require workers. We do not know which will dominate on net for any given occupation, or for total employment as a whole. However, McKinsey Global Institute (MGI June 2018) estimate that forces for job creation could outweigh the job-eliminating effects, generating net job growth globally.

Further, the estimates of Frey and Osborne (2013) abstract from trends that might slow the progress of automation in the labor market. If labor is relatively cheap, it will tend to reduce the adoption of labor-saving technology. In addition, regulatory concerns and politics may reduce the adoption of technology, see for example the regulatory and legal issues around driverless cars. As always, note that forecasting is difficult, especially when it comes to the future course of technological advancement.

Frey and Osborne (2013) also abstract from demographic trends (aging of the baby-boom generation) which will be (or already are) generating labor shortages. In the face of these emerging labor shortages, automation will be needed to keep output growing.

MGI and other researchers emphasize that the impacts of increased automation will require workers to manage and trouble-shoot automated systems. Thus, much of the future workforce will need to be comfortable and capable of working with technology. This will require increased technical skill and education. In addition, creative and social skills will likely become increasingly important in the future.

In particular, MGI (May 2018) estimate that the following skill sets will be in more demand in coming decades: advanced IT skills and programming; basic digital skills, entrepreneurship and initiative taking, leadership and managing others, creativity, and complex information processing and interpretation. Skills likely to be less demand in coming decades include basic data input and processing; basic literacy, numeracy, and communication; general equipment operation and navigation; inspecting and monitoring.

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