Journal of Applied Econometric (JoAE)
Vol. 1, No. 1, 2025, pp. 16-22
ISSN: xxxx-xxxx, DOI: ...

THE ROLE OF DIGITAL TRANSFORMATION IN LABOR MARKET CHANGES: AN ECONOMETRIC ANALYSIS OF THE IMPACT OF AUTOMATION ON THE MANUFACTURING SECTOR

Rani Santika[1], Rafi Farizki[2]
[1] Universitas Muhammadiyah Prof Dr Hamka, Indonesia
[2] Sekolah Tinggi Manajemen Informatika Informatika dan Komputer LIKMI, Indonesia

Keywords:

digital transformation, automation technology, labor market dynamics, econometrics, manufacturing sector

ABSTRACT

Digital transformation is fundamentally changing the landscape of the global labor market, especially in the manufacturing sector that is increasingly adopting automation technology. Developing countries, including Indonesia, face significant challenges in responding to shifting skills needs due to these technological developments. This study aims to analyze in depth the impact of automation on labor market dynamics in the manufacturing sector, focusing on changing patterns of skills demand and their implications for labor productivity and resilience. Using a sophisticated econometric approach, this study utilizes panel data from the manufacturing industry in Indonesia over the past ten years. The analysis was conducted using fixed-effects and multivariate regression methods to assess the relationship between the adoption rate of automation technology and key variables of the labor market, such as changes in skill composition, wage levels, and demand for skilled versus unskilled labor. The results of the analysis show that there is a significant impact of automation in reducing the demand for non-skilled labor, while specialized skills, especially in the field of technology and maintenance, are experiencing an increase in demand. This research provides important insights for the formulation of policies that support the upskilling of the workforce in the face of the digital era, and shows that the sustainability of the manufacturing sector is highly dependent on the adaptation and development of technology-based skills.

Corresponding Author:

Rani Santika
Universitas Muhammadiyah Prof Dr Hamka, Jakarta Selatan, Indonesia
Email: rsantika851@gmail.com

1. INTRODUCTION

Digital transformation and technological automation have dramatically changed the structure of the global labor market, especially in the manufacturing sector. The digitalization process, accelerated by the industrial revolution 4.0, is driving the increased adoption of advanced technologies such as artificial intelligence, robotics, and automation systems that overhaul traditional production systems. In the global context, the manufacturing sector, which previously relied on manual labor, is now shifting to more efficient and technology-based systems. These changes not only affect production patterns

but also significantly change the skills needs of the workforce, shifting demand from traditional jobs to digital technology-based and high-skill jobs (Brynjolfsson & McAfee, 2014; Frey & Osborne, 2017; Schwab, 2017).

In Indonesia, the manufacturing sector is an important pillar for the economy, absorbing a large number of workers and contributing significantly to the Gross Domestic Product (GDP). However, advances in automation present serious challenges for a workforce that does not yet have adequate digital skills. The transition to automation has the potential to increase productivity, but at the same time create a structural threat of unemployment for a digitally untrained workforce (Acemoglu & Restrepo, 2020; D. H. Autor & Dorn, 2013; Graetz & Michaels, 2018). This challenge is increasingly complex in developing countries such as Indonesia, where the proportion of low-educated workers is still quite high in the manufacturing sector, thus increasing the risk of mismatch of skills needed in the digital era.

This creates a major dilemma for governments and industry to ensure that the benefits of technology can be enjoyed without causing major social disruption. On the one hand, automation offers opportunities to improve operational efficiency, lower production costs, and improve industrial competitiveness. However, on the other hand, its destructive impact on unskilled workers or workers with irrelevant skills is a critical issue that requires serious attention. Automation has the potential to shift low-wage labor to the informal sector or even result in unemployment if it is not balanced with upskilling (Arntz, 2016; D. H. Autor et al., 2003; Baldwin, 2019).

Previous research has shown that automation has a significant impact on changing workforce skills needs in developed countries. (D. Autor & Salomons, 2018) found that automation drives an increase in demand for high-skilled and technical workers, but reduces the demand for labor in low-income sectors. In the United States and Europe, the results show an increase in the need for technology skills and complex data analysis in response to advances in automation (Acemoglu & Restrepo, 2018; Bessen, 2016; Chui et al., 2016). However, the literature on the same impact in developing countries, especially Indonesia, is still limited and leaves a wide research gap.

Relevant studies in developing countries have focused more on the impact of automation on economic aspects in general, but not many have specifically examined its impact on shifting skills needs in the manufacturing sector. This raises an important research gap, considering that the manufacturing sector in developing countries has different characteristics compared to developed countries, both in terms of labor profile and readiness for digital technology adoption (Bank, 2019). In this context, there is an urgent need to understand the real impact of automation on the structure of the labor market and the shift in labor skills in Indonesia's manufacturing sector, which has not been widely explored in previous research.

This study offers novelty with an econometric approach that is used to analyze in depth the impact of automation on skill demand and employment patterns in Indonesia's manufacturing sector. By utilizing panel data and fixed-effects methods, this study is able to provide a more accurate analysis of the relationship between the adoption rate of automation technology and labor market variables, such as changes in skill composition, wage levels, and the need for skilled versus unskilled labor. The results of this study are expected to provide a more in-depth picture of the direct and indirect impacts of automation on the labor structure in the manufacturing sector (D. H. Autor, 2015; Bessen, 2016; Choudhury et al., 2020).

The main objective of this study is to make a real contribution to the academic literature on the impact of digital transformation and automation on the labor market in

ISSN: XXXX-XXXX

developing countries, especially in the Indonesian manufacturing sector. This research not only aims to identify shifting skills needs in the digital era, but also offers policy recommendations to prepare the workforce for technological change. The recommendations are expected to help the industry and the government to develop appropriate skills development strategies to ensure the sustainability of the manufacturing sector in Indonesia in the face of the era of industrial revolution 4.0 (Chui & Francisco, 2017; Schwab, 2017).

2. METHOD

This study uses a quantitative approach with econometric methods, which aims to evaluate the impact of the adoption of automation technology on labor market changes in the manufacturing sector in Indonesia. This type of research is *explanatory research*, which examines the causal relationship between the application of automation and labor market dynamics. This study is designed to identify shifts in skills demand and changes in the composition of the workforce in the manufacturing industry as an impact of digital transformation.

The study population is manufacturing companies in Indonesia that are registered with the Central Statistics Agency (BPS) and have adopted digital technology in their operations for the past ten years. The sample was selected using *a purposive sampling* technique, with the criteria of companies that have significant automation implementation. These samples were taken from various manufacturing sub-sectors, such as textiles, food and beverage, electronics, and automotive, to get a representative picture of the impact of automation on the workforce across industries.

The main instruments in this study are secondary data collected from the company's annual report, panel data from BPS, as well as a survey on the use of automation technology and skills needs in the manufacturing sector. The research variables include the level of automation, the composition of the workforce based on skills, wage levels, and the number of skilled and non-skilled workers. The use of secondary data from official sources and company reports increases the accuracy and validity of research results.

Data collection is carried out using documentation techniques and secondary data collection through access to industry databases from BPS and company reports. In addition, interviews with human resource managers in several sample companies were conducted to obtain more detailed data on automation-related workforce policies. The use of this technique helps provide an in-depth perspective in analyzing the impact of digital transformation on workforce structures.

The research procedure begins with the selection of samples based on predetermined criteria, then continues with secondary data collection and structured interviews. After that, the data is processed to obtain the main variables that are in accordance with the purpose of econometric analysis. Data processing is carried out carefully to ensure that each stage is in accordance with scientific research principles, including the validity and reliability of the data produced.

Data analysis techniques are carried out using econometric methods, especially *fixed-effects* models to control unobserved variables that can affect the relationship between automation and changing skill needs. Multivariate regression analysis is used to identify the influence of automation adoption on the labor market, such as changes in labor composition and wage levels. This model provides an in-depth understanding of the long-term impact of digital transformation in the manufacturing sector.

Through this analysis, this study is expected to present comprehensive and accurate results related to the impact of automation on the labor market in the Indonesian manufacturing sector. The findings of this study will be useful for the formulation of policies that support the improvement of workforce skills in the digital era and can be the basis for the development of adaptation strategies for the manufacturing industry in Indonesia

Table 1. The Result of The Fixed-Effects Model Test

Variable	Coefficient	Std. Error	t-Statistics	p-Value	Confidence Interval (95%)
Automation	0.345	0.056	6.16	0.000	[0.235, 0.455]
Wage Levels	0.128	0.032	4.00	0.001	[0.065, 0.191]
Skilled Workforce	0.217	0.048	4.52	0.000	[0.122, 0.312]
Unskilled Labor	-0.153	0.047	-3.26	0.002	[-0.246, -0.060]
R-squared	0.67				
Adjusted R-squared	0.64				
F-statistic	15.32			0.000	

The table above shows the influence of independent variables such as automation, wage levels, skilled labor, and unskilled labor on the labor market in the manufacturing sector. The positive coefficients on the variables of skilled labor and wage levels suggest that the adoption of automation drives the need for a high-skilled workforce and increases average wages. In contrast, the negative coefficient in the unskilled workforce confirms that automation reduces the demand for low-skilled labor.

3. RESULTS AND DISCUSSION

The Impact of Automation on Shifting Skills Needs in the Manufacturing Sector

This study reveals that the adoption of automation technology in Indonesia's manufacturing sector has led to a significant shift in the skills needs of the workforce. Increased automation results in an increase in demand for highly skilled workers, especially in the operation and maintenance of digital and robotics technologies, while unskilled workers experience a decline in demand (D. H. Autor & Dorn, 2013; Frey & Osborne, 2017; Schwab, 2017). These findings are in line with global trends suggesting that automation is replacing manual and routine work, shifting to jobs that require more complex analytical and technical skills (Acemoglu & Restrepo, 2020; Bessen, 2016; Brynjolfsson & McAfee, 2014).

An analysis of the automation coefficient showed a significant positive relationship with the need for skilled labor, with a coefficient value of 0.217 ($p < 0.01$), indicating that increased automation leads to a higher demand for a workforce with specialized skills (Autor & Salomons, 2018; Arntz et al., 2016; Baldwin, 2019). In contrast, the non-skilled labor variable showed a negative coefficient, indicating a reduction in demand for jobs that do not require technological skills (Graetz & Michaels, 2018; Schwab, 2017).

Table 2. Coefficient of the Effect of Automation on Labor Needs in the Manufacturing Sector

Variable	Coefficient	Significance
Skilled Workforce	0.217	0.000
Unskilled Labor	-0.153	0.002

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Source: Autor & Dorn, 2013; Graetz & Michaels, 2018; Schwab, 2017.

The Link of Automation to the Wage Rate of Skilled Workers

The findings show that the increased adoption of automation contributes to an increase in the average wage of skilled workers. This is due to a shift in demand for a higher-skilled workforce, which causes companies to invest more in a technically capable workforce (D. H. Autor, 2015). The wage rate coefficient showed a positive number of 0.128, indicating that automation drove wage increases for workers who adapted to technology, while non-skilled workers experienced stagnation or decreased compensation (Chui & Francisco, 2017).

Increased productivity through automation allows companies to reduce production costs, which are often allocated to retain skilled labor at higher wage levels (Bessen, 2016; Deloitte, 2020; McKinsey Global Institute, 2017). The following diagram illustrates the relationship between the level of automation, the increase in skilled labor wages, and the stagnation of non-skilled labor wages:

Figure 1. The Effect of Automation on Skill-Based Wage RatesSource: Autor & Salomons, 2018; Schwab, 2017; World Economic Forum, 2021.

The diagram above illustrates the impact of automation on wage levels based on the skill category of the workforce. Skilled workers are experiencing an increase in wages and productivity along with the adoption of automation (marked with a green bar), while unskilled workers are facing stagnation or even a decline in wages (marked with a red bar). This diagram illustrates the shift in corporate investment to retain a highly skilled workforce in response to evolving technological needs.

Policy Challenges in Improving Workforce Skills in the Age of Automation

The results of this study show the need for proactive policies in improving labor skills to adjust to the needs of the technology-based labor market. The policy implications of these outcomes are the importance of collaboration between governments, industry, and educational institutions to design programs that lead to high digital and technical skills (Autor et al., 2015; Schwab, 2017; Bessen, 2019). Developed countries have successfully implemented upskilling policies that allow their workforce to adapt to technology, thereby

reducing the negative impact of automation (Acemoglu & Restrepo, 2018; Brynjolfsson & McAfee, 2014; Graetz & Michaels, 2018).

In Indonesia, the government can facilitate companies in providing technology-based training for the workforce, as well as encourage vocational education oriented to the needs of industry 4.0 (World Economic Forum, 2021; Deloitte, 2020; McKinsey Global Institute, 2017). The study emphasizes that without training support, unskilled workers will be increasingly vulnerable, increasing the risk of economic inequality (Autor & Dorn, 2013; Chui et al., 2016; Baldwin, 2019).

The Future of the Workforce in the Manufacturing Sector: Challenges and Opportunities

The long-term view shows that automation in the manufacturing sector will continue to increase, and adaptation is a crucial factor for the workforce and labor policy. The results of this study confirm that changes in the curriculum of high-tech education and skills training are very important to prepare the future workforce to face an increasingly technologically advanced work environment (Schwab, 2016; Autor et al., 2015; McKinsey Global Institute, 2017).

Countries that have integrated automation with education strategies have shown success in creating a workforce that is ready to adapt to technology. This experience is relevant for Indonesia, where investment in technology-based workforce training will be a decisive factor in maintaining the competitiveness of the manufacturing industry (Autor & Salomons, 2018; Frey & Osborne, 2017; Chui et al., 2016).

In conclusion, the results of this study support the policy of improving digital skills as a strategic step to respond to the impact of automation in the manufacturing sector. Improving relevant skills will enable Indonesia to take advantage of the opportunities arising from digital transformation while mitigating the challenges presented by automation

4. CONCLUSION

This research provides in-depth insights into the impact of digital transformation through automation on labor market dynamics in Indonesia's manufacturing sector. The analysis shows that the adoption of automation has shifted the demand for the workforce from manual and routine skills to high-tech skills relevant to the operation and maintenance of digital technologies and robotic systems. This increase in demand for skilled labor indicates a significant structural transition in the manufacturing sector, where companies are increasingly relying on a workforce capable of supporting operational efficiency through more advanced digital skills. In contrast, the unskilled workforce is experiencing a decline in demand, indicating that those who are unable to adapt to the needs of new technologies are becoming increasingly vulnerable to the impacts of automation.

The study also found that increased automation has a direct effect on increasing the wage level of skilled workers, reflecting the added value provided by technical skills in increasing productivity. On the other hand, the unskilled workforce is experiencing stagnation or even a decline in wages, showing that automation is not only a matter of efficiency but also brings the implications of inequality that needs to be strategically managed. These results underscore the importance of policies that focus not only on increasing technology adoption, but also on developing workforce skills to ensure their readiness to face the challenges of the industry 4.0 era. Intensive training policies focused on digital and technical skills can help Indonesia's workforce adapt to these structural changes, support the sustainability of the manufacturing sector, and strengthen the competitiveness of the national economy

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