Journal of Business and Social Development
Volume 13 Number 1, March 2025: 34-47
eISSN: 2600-9668

THE CHALLENGES FOR SKILLED WORKERS IN MALAYSIA AMIDST INDUSTRY 4.0

NOORAZEELA ZAINOL ABIDIN[1,2]*, UMMI NAIEMAH SARAIH[1,2], HAFIRDA AKMA MUSADDAD[1] AND NURAINI ABDULLAH[1]

[1]Faculty of Business and Communication, Universiti Malaysia Perlis, 01000 Kangar, Perlis, Malaysia. [2]Centre of Excellence for Social Innovation and Sustainability, Universiti Malaysia Perlis, 01000, Kangar, Perlis, Malaysia.

**Corresponding author: noorazeela@unimap.edu.my*
http://doi.org/10.46754/jbsd.2025.03.003
Received: 12 August 2024 Revised:23 October 2024 Accepted: 23 November 2024 Published: 15 March 2025

Abstract: This study investigates the challenges for skilled workers in Malaysia during the transition to Industry 4.0. The rapid pace of technological advancements and shifting industrial demands create significant obstacles for the skilled workforce. Analysing data from 1990 to 2021, the research assesses the effects of high-skilled and semi-skilled workers, as well as foreign direct investment (FDI), on research and development (R&D) activities in Malaysia. Utilising the ARDL model, the study explores both short- and long-term impacts of these variables on R&D expenditure. The findings indicate that high-skilled workers have a positive effect on R&D in the short-term, emphasising their crucial role in driving innovation. However, their long-term impact is less pronounced, potentially due to diminishing returns or inadequate R&D investment. In contrast, semi-skilled workers negatively influence R&D outcomes due to their limited technical expertise and the additional resources required for supervision and training. FDI is shown to have a positive effect on R&D in both the short and long run, underscoring the importance of financial resources for supporting innovation and research. Based on these results, the study recommends several policy actions. It suggests enhancing educational programmes to better prepare the workforce for Industry 4.0 demands, increasing government funding for R&D, and supporting employer-led training initiatives. These measures are essential for equipping Malaysia's workforce to navigate the challenges of Industry 4.0 and to sustain its competitive edge in the global economy.

Keywords: FDI, high skilled, R&D expenditure, semi-skilled, technology.

Introduction

The Fourth Industrial Revolution (IR 4.0) is characterised by the fusion of physical, digital, and biological systems, leading to transformative changes across various industries. In Malaysia, the government has recognised the importance of IR 4.0 as a key driver of economic growth and competitiveness. Various initiatives, such as the National Policy on Industry 4.0 (Industry4WRD), have been introduced to support the adoption of new technologies and enhance the country's manufacturing sector.

Despite these efforts, Malaysia faces significant challenges in preparing its workforce for IR 4.0. The rapid advancement of technology requires workers to continuously update their skills and competencies. However, the current education and training systems may not be fully equipped to meet the evolving demands of the industry. Additionally, there is a growing skills mismatch, where the qualifications and expertise of the workforce do not align with the needs of modern industries.

The onset of the Fourth Industrial Revolution (IR 4.0) has significantly transformed the global economy, revolutionising industries by incorporating advanced technologies such as automation, artificial intelligence (AI), the Internet of

Things (IoT), and big data analytics. In Malaysia, these technological advancements are driving industries toward greater efficiency and innovation.

However, the rapid pace of technological change also presents considerable challenges, particularly for the skilled workforce. As industries evolve, there is a growing demand for workers who possess not only technical skills but also the ability to adapt to new and emerging technologies. This transition has exposed gaps in the current skill sets of Malaysian workers, raising concerns about their readiness to thrive in an IR 4.0 environment.

According to Cordero (1999), research and development (R&D) professionals must acquire and maintain process knowledge and skills to effectively contribute to achieving process outcomes within cross-functional teams. Knowledge competencies and R&D activities are widely recognised as crucial drivers of innovation, a topic extensively covered in the literature (Basit *et al*., 2022). Lucas's work is foundational in understanding the role of human capital, including skilled labour, in driving economic growth and development. It lays the groundwork for the importance of skilled workers in innovation and R&D (Lucas, 1988).

In Malaysia, a skilled worker is an individual who possesses specialised knowledge, expertise, or technical skills acquired through formal education, vocational training, or hands-on experience. These workers are essential across various industries as they perform tasks that require specific competencies, often involving complex machinery, technology, or processes. Skilled workers include technical and vocational professionals such as electricians, plumbers, and welders, as well as professionals in specialized fields like engineers, IT specialists, and healthcare practitioners.

Additionally, skilled tradespeople, such as carpenters, chefs, and artisans, play a crucial role in sectors that require craftsmanship and precision. Skilled workers are vital to Malaysia's economic development, contributing significantly to productivity, innovation, and industry efficiency. As the country advances toward becoming a high-income nation, the demand for skilled workers, particularly those with expertise in emerging technologies like automation and artificial intelligence, is increasing.

However, these workers face challenges such as skills mismatches, the need for continuous learning, economic disparities, and concerns about job security due to the rise of automation. To support skilled workers, the Malaysian government has implemented initiatives like Industry4WRD and expanded Technical and Vocational Education and Training (TVET) programmes, emphasising the importance of upskilling and lifelong learning to maintain the country's global competitiveness.

One of the most pressing issues facing the Malaysian workforce in the IR 4.0 era is the significant skills gap and mismatch. While IR 4.0 demands advanced technical skills, such as data analytics, programming, and automation, many workers lack these competencies.

Traditional educational systems have not fully adapted to the new technological demands, resulting in a workforce that is not adequately prepared for the complexities of modern industries. This mismatch between the skills possessed by workers and those required by employers can hinder Malaysia's progress in adopting IR 4.0 technologies. Besides, certain industries, such as electronics, automotive, and chemicals, are at the forefront of adopting IR 4.0 technologies in Malaysia.

However, these industries are also experiencing the most significant skills shortages, as they require workers with specialised knowledge in automation, precision engineering, and digital manufacturing. The mismatch between industry needs and workforce capabilities slows down technological adoption and reduces competitiveness on a global scale. Other than that, the rapid pace of technological advancements requires continuous learning and upskilling for workers to remain relevant in their fields.

However, many Malaysian workers lack access to effective training programmes to help them acquire new skills or upgrade existing ones. Moreover, workers are often reluctant to engage in lifelong learning due to time constraints, financial limitations, or a lack of awareness about the importance of upskilling. This challenge is exacerbated by the fact that many employers may not prioritise employee training and development, further limiting worker opportunities to improve their skills.

This study contributes to the existing body of literature by specifically addressing the challenges faced by skilled workers in Malaysia during the transition to Industry 4.0. While previous research has explored the impact of technological advancements on labour markets globally, few studies have focused on Malaysia's unique industrial landscape, particularly using the Autoregressive Distributed Lag (ARDL) model.

This study fills this gap by analysing the short- and long-term effects of high-skilled and semi-skilled workers, as well as FDI, on R&D) activities in Malaysia from 1990 to 2021. Unlike previous studies, which may have focused primarily on labour outcomes or economic growth, this research integrates workforce dynamics and R&D expenditure, offering a more nuanced understanding of how skilled labour affects innovation. Additionally, this study differentiates itself by emphasising the critical role of education and policy reforms in preparing Malaysia's workforce for the challenges posed by Industry 4.0.

Consequently, this study can enhance previous research on the challenges faced by skilled workers during Industrial Revolution 4.0 in Malaysia by applying the ARDL model approach. The study is organised into five primary sections. The second section reviews previous research, while the third section focuses on the methodology used. The fourth section presents the study's results, and the final section offers the conclusion.

Literature Review

The relationship between R&D and workforce quality, particularly with respect to high-skilled and semi-skilled workers, has been extensively studied. Previous research consistently highlights the crucial role of high-skilled labour in fostering innovation and advancing R&D, while semi-skilled workers often have a more complex and sometimes negative influence on R&D outcomes.

According to Danial (2019), Industry 4.0 merges traditional manufacturing with technologies like IoT, which enhances machine-to-machine communication and data sharing, enabling better decision-making. This transformation requires a workforce skilled in Big Data, AI, advanced analytics, robotics, and automation. Automation can even predict and resolve issues autonomously.

However, Malaysia lacks a standardised system to produce graduates equipped for Industry 4.0, as university curricula remain outdated and fail to meet current industry demands.

Ahmad Sekak *et al.* (2022) found that implementing Industry 4.0 in the construction sector presents significant challenges due to its unpredictable nature, requiring contractors to be more competitive to navigate these challenges.

However, the findings also highlight that Industry 4.0 provides opportunities for contractors to work more efficiently and adopt a more strategic approach to project planning. Thus, the challenges and opportunities of Industry 4.0 are both evident and impactful. In addition, Yusoff *et al.* (2023) showed that Malaysian manufacturing SMEs acknowledge the benefits of adopting Industry 4.0 for their businesses, economy, and society.

However, they face challenges such as financial constraints and a lack of employee knowledge and skills needed to effectively implement and operate Industry 4.0 technologies. The study by Wang (2024) reveals that highly skilled employees from R&D-investing firms experience better career outcomes, such as higher wage growth and career progression, compared to those from non-investing firms.

However, this group shows little interest in entrepreneurship. These findings underline the positive impact of R&D and provide valuable insights for policy development. Basit *et al.* (2022) demonstrate that R&D activities and knowledge competencies are positively related to various forms of innovation, influenced by how firms perceive their competitive environment, including challenges such as outdated products/services and strong global competition.

Meanwhile, Sokhanvar and Ciftcioglu (2022) found that increased R&D has a negative effect on high-skilled labour employment, though it does not significantly impact low-skilled and medium-skilled labour in the UK.

Otero *et al.* (2023) highlighted that high-skilled workplaces are not immune to automation, and worker protection largely depends on a company's competitive strategies and management attitudes. These findings emphasise the importance of social relationships in discussions about the future of work and challenge solutions that focus solely on skills training and educational reforms to protect workers and promote inclusive labour markets.

Carpenter (2017) noted that the R&D sector requires specific skills to thrive, with Ph.D.s becoming increasingly essential for R&D roles. Other key skills, including data analysis, problem-solving, communication, and specialised abilities such as using laboratory equipment and understanding regulatory requirements, are also highly valued.

Padeli *et al.* (2024) discuss a rapidly evolving environment where organisations adopt 4IR technologies to improve knowledge creation, storage, sharing, and application. The review stresses the importance of a flexible and strategic knowledge management (KM) approach in the 4IR era, emphasising the roles of organizational culture, leadership, and technological infrastructure in fostering effective KM practices. Piva and Vivarelli (2009) found that the widely recognised technology-push and demand-pull hypotheses influence R&D investment.

Furthermore, the study demonstrates that a firm's skill endowment significantly contributes to increasing R&D investments. Skilled employees and patents have a positive effect on the total capital turnover of Italian innovative startups. R&D investments primarily impact the number of employees in these startups (Matricano, 2020).

Saka and Orhan (2024) found that technology negatively impacts both high-skilled and low-skilled employment in developing countries, with the effect being more pronounced on low-skilled jobs. Aiyetan and Dillip (2018) identified factors such as investment, wages, talent management, work environment, training, experience, and government policy as contributors to the skilled labour shortage, which negatively affects work quality, productivity, and scheduling.

Improving labor wages, talent management, and staff development can help address this issue and increase the skilled labour pool. Furthermore, Li *et al.* (2013) showed that locally-recruited R&D personnel have a limited impact on innovation. While they contribute marginally to R&D output through technological knowledge, they struggle to convert R&D spending into successful patents due to a lack of technology management skills.

In contrast, expatriate R&D personnel significantly contribute to both R&D output and patent success. A cross-sectional analysis by Abowd *et al.* (2007) found a strong positive association between sophisticated technology and skill. More advanced technology companies employ more high-ability workers but fewer high-experience workers.

Lee and Clarke (2019) showed that STEM-intensive high-tech or digital economy companies have a positive jobs multiplier, with each 10 new high-tech positions creating seven local non-tradeable service jobs, six of which are low-skilled. High pay assists mid-skilled workers without increasing employment rates.

While low-skilled individuals benefit from increased employment rates, their jobs are often low-paying service work which lowers average salaries, especially considering housing costs. Diaz *et al.* (2020) found that innovation improves employment during tough times, with a much greater influence on high-skilled workers.

These findings apply to all industries but are more pronounced in high-tech sectors. Product and process improvements may have explained 13% of the crisis-era difference in high- and low-skilled employment.

In summary, previous studies consistently show that high-skilled workers are essential for driving innovation and enhancing R&D outcomes, while semi-skilled workers often contribute less favourably due to their limited technical capabilities. The literature suggests that to optimise R&D productivity, industries must prioritise the development and integration of high-skilled labour while addressing skill gaps in the semi-skilled workforce.

Methodology

This study explores the challenges faced by skilled workers during the Industrial Revolution 4.0 in Malaysia from 1990 to 2021. The research focuses on R&D expenditure as the dependent variable, while high-skilled workers, semi-skilled workers, and foreign direct investment serve as the independent variables.

Table 1: Variable description

Variable	Descriptions	Source
Research and development (R&D) expenditure	R&D expenditure data typically includes the total amount spent on research and development activities, often expressed as a percentage of GDP	World Bank
High-skilled workers	This data reflects the number or percentage of workers categorised as "high-skilled", based on their education, expertise, and role in the workforce	International Labour Organization (ILO)
Semi-skilled workers	Data for semi-skilled workers includes the number or percentage of workers with moderate skills, typically acquired through vocational training or limited formal education	International Labour Organization (ILO)
Foreign direct investment (FDI)	FDI data includes the total inflows of foreign capital into a country, which can influence a range of economic factors, including R&D expenditure	World Bank

The study employs the ARDL approach, with the following model specification:

$$RND_t = \beta 0 + \beta 1HS_t + \beta 2SS_t + \beta 3FDI_t + \varepsilon t \tag{1}$$

In this context, RND denotes research and development expenditure, HS stands for high-skilled workers, SS represents semi-skilled workers, and FDI refers to foreign direct investment. The subscript t indicates the year. β denotes the regression coefficients for each variable, and ϵ is the error term. To prevent inaccurate estimates, several variables in equation (1) will be logged. Consequently, equation (2) will be formulated as follows:

$$RND_t = \beta 0 + \beta 1HS_t + \beta 2SS_t + \beta 3\ln FDI_t + \varepsilon t \tag{2}$$

A unit root test using the Augmented Dickey-Fuller (ADF) method was employed in this study to assess data stationarity (equation 3).

$$\Delta Y_t = \beta 1 + \delta Y_{t-1} + \alpha \sum^p \Delta Y_{t-1} + U_t \tag{3}$$

The null hypothesis is accepted if the result shows insignificance ($\delta = 0$), indicating that the data is either stationary or has a single source. Conversely, the alternative hypothesis is accepted if the data is significant ($\delta \neq 0$), suggesting that the data does not exhibit stationarity or has a unit root. This approach illustrates how the dependent variable responds to changes in the independent variable over the long term.

Unlike the Johansen cointegration method, which requires a large sample size, this approach can be effectively used with smaller samples.

The ARDL method also offers the advantage of providing long-term estimates. In the ARDL test, various tests are conducted, including the bound test, cointegration test, diagnostic test, error correction model (ECM), cumulative residual recursive sum (CUSUM), and cumulative square residual sum (CUSUMSQ). Equation (4) outlines a model for analysing both long- and short-term relationships between R&D and independent variables.

$$\Delta RND_t = \beta_0 + \emptyset_i RND_{t-1} + \beta_1' HS + \beta_2' SS_t + \beta_3' lnFDI_t + \sum_{j=1}^{p-1} \lambda_j \, \Delta RND_{t-j} + \sum_{j=0}^{q-1} \delta_{1ij}' \, \Delta HS_{t-j} + \sum_{j=0}^{q-1} \delta_{2ij}' \, \Delta SS_{t-j} + \sum_{j=0}^{q-1} \delta_{3ij}' \, \Delta lnFDI_{t-j} + \varepsilon_j \quad (4)$$

To ensure the model's validity, several diagnostic tests are required, including the Breusch-Godfrey serial correlation test, the Ramsey stability test, the Jarque-Bera test, and the heteroscedasticity test. Non-significant results from these tests suggest that the model is optimal. After this, the stability of equation model (4) can be evaluated using the CUSUM and CUSUMSQ tests. The model will be deemed stable if the CUSUM and CUSUMSQ lines stay within the 5% critical bounds.

Findings

Table 2 presents the unit root test results for each variable. The analysis indicates that all variables are stationary at the first difference, I(1), for both intercept and intercept with trend, with significance at the 5% level according to the ADF unit root test. Stationarity at the first difference helps prevent inaccurate regression estimates. While the time-series data in this study are stationary at the first difference but not at the level, I(0), this suggests a likely long-term relationship within the data.

Table 2: Unit root test

Variables	Intercept				Trend and Intercept			
	I(0)		I(1)		I(0)		I(1)	
	t-statistic	Prob.	t-statistic	Prob.	t-statistic	Prob.	t-statistic	Prob.
RND	-2.469	0.1324	-10.770**	0.0000	-4.073**	0.0163	-11.925**	0.0000
HS	-1.695	0.4233	-7.444**	0.0000	-2.158	0.4940	-7.308**	0.0000
SS	-3.706**	0.0090	-4.019**	0.0048	-6.781**	0.0001	-4.197**	0.0142
LNFDI	-5.010**	0.0003	-6.536**	0.0000	-5.391**	0.0007	-6.441**	0.0001

Note: ** denote significant at 5%

Before estimating the ARDL model, it is essential to conduct ARDL boundary testing to verify if a cointegration relationship exists between the dependent and independent variables. The results of this boundary test are shown in Table 3. The cointegration analysis reveals a long-term relationship between the variables, with an F-statistic of 9.3043 surpassing the upper critical value. This finding leads to the rejection of the null hypothesis at the 1% significance level. With the long-term relationship confirmed, the analysis can proceed with regression using the ARDL model.

Table 3: Bound test

Test Statistic	**Value**	
F-statistic	9.3043***	
Critical Values		
Significance	**Lower Bound I(0)**	**Upper Bound I(1)**
10%	2.62	3.53
5%	3.16	4.19
1%	4.43	5.81

Table 4 presents the long-run estimation results. According to the table, high-skilled workers do not have a significant relationship with R&D. This lack of significance may be due to insufficient and sustained investment in R&D activities. Even with highly skilled personnel, without adequate funding and resources, the impact on R&D may not be realised. In contrast, semi-skilled workers show a negative and significant relationship with R&D.

Specifically, a 1% increase in semi-skilled workers is associated with a 36.68% decrease in R&D. This is because semi-skilled workers often lack the advanced technical knowledge and specialised skills required for complex R&D tasks. Their limited expertise can constrain their ability to contribute effectively to sophisticated research projects, leading to slower progress and less innovative outcomes. Additionally, semi-skilled workers typically require more supervision and training, which can divert time and resources away from R&D activities, slowing down the research process and reducing overall efficiency.

This result is consistent with previous research by Sokhanvar and Ciftcioglu (2022), who found that semi-skilled workers often lack the advanced technical knowledge necessary to contribute meaningfully to R&D. Semi-skilled workers require additional supervision and training, which diverts resources from innovation activities, thereby slowing down R&D progress.

Moreover, the Aiyetan and Dillip (2018) study supports this finding, suggesting that the involvement of semi-skilled workers in R&D activities leads to inefficiencies due to their limited expertise.

On the other hand, FDI shows a positive and significant relationship with R&D. A 1% increase in FDI is associated with a 4.06% increase in R&D. FDI often brings substantial financial resources into a country or organisation, which can be allocated to R&D activities. This influx of capital supports new research projects, the development of innovative technologies, and the costs associated with advanced R&D activities.

This result is consistent with the work of Piva and Vivarelli (2009), who highlighted the critical role of FDI in providing financial resources for R&D activities. FDI often brings in not just capital but also knowledge transfer, technological know-how, and advanced business practices, which help fuel R&D efforts.

Table 4: ARDL long-run estimation result

Variable	Coefficient	Prob.
HS	7.7189	0.3271
SS	-36.6813**	0.0003
LNFDI	4.0574**	0.0130
C	21.3241**	0.0028

Note: ** represent significance at 5%

Table 5 presents the results of the short-run ARDL estimation test. The Error Correction Term (ECT) indicates the rate at which the model adjusts, with a negative value suggesting that the variables will realign in the long run. For Malaysia, 43.20% of the adjustment occurs within a year. The R-squared value of 0.9687 demonstrates that approximately 96.87% of the variability has been accounted for.

The findings reveal that high-skilled workers (HS) have a positive and significant impact on R&D in the short run, with a 1% increase in high-skilled workers associated with a 3.33% increase in R&D expenditure.

High-skilled workers contribute specialised knowledge and advanced technical expertise to R&D projects, allowing them to tackle complex problems and apply sophisticated techniques. This expertise leads to immediate improvements in research quality and innovation outcomes. Their efficiency and effectiveness in the R&D process result in quicker results and more rapid advancements.

This aligns with the findings of Basit *et al.* (2022), who emphasise the role of high-skilled labour in promoting innovation and technological advancement. High-skilled workers bring specialised knowledge and technical expertise, which are critical for driving R&D efforts.

In addition, semi-skilled workers (SS) also show a positive and significant impact on R&D in the short run, with a 1% increase in semi-skilled workers associated with an 11% increase in R&D expenditure. Moreover, foreign direct investment (FDI) increase in semi-skilled workers associated with an 11% increase in R&D expenditure. Moreover, FDI demonstrates a positive and significant impact on R&D in the short run, with a 1% increase in FDI associated with a 1.75% increase in R&D expenditure.

Table 5: ARDL short-run estimation results

Variable	Coefficient	Prob.
D(HS)	3.3342**	0.0341
D(SS)	11.0005**	0.0008
D(LNFDI)	1.7526**	0.0071
ECT(-1)	-0.4320**	0.0015
R-squared = 0.9687	Adjusted R-squared = 0.9155	

Note: ** represents significance at 5%

Table 6 details the diagnostic procedures applied to evaluate the data and address potential issues. The tests conducted include the Jarque-Bera normality test, the Breusch-Godfrey serial correlation test, the Breusch-Pagan test for heteroskedasticity, and the Ramsey RESET stability test.

According to the results presented in Table 5, each of these tests—Jarque-Bera, Breusch-Godfrey, heteroskedasticity, and Ramsey RESET—showed no significant problems. The model appears to be free of economic issues, as all p-values for the tests are above the 10% significance level.22

Table 6: Diagnostic test result

Test Statistic	F-statistic
Jarque-Bera	3.6584 (0.1605)
Serial correlation	1.1863 (0.3538)
Heteroscedasticity test	0.3446 (0.9743)
Ramsey RESET test	0.0179 (0.8966)

Figures 1 and 2 illustrate the plots for the cumulative sum of squares of recursive residuals and the cumulative total of recursive residuals, respectively. These plots are instrumental in verifying the stability of the model.

For both CUSUM tests, the blue line is within the red lines. The CUSUM test is significant at the 5% level. Based on the diagnostic and stability tests, the econometric model used in this study is capable of yielding optimal results from the analysis.

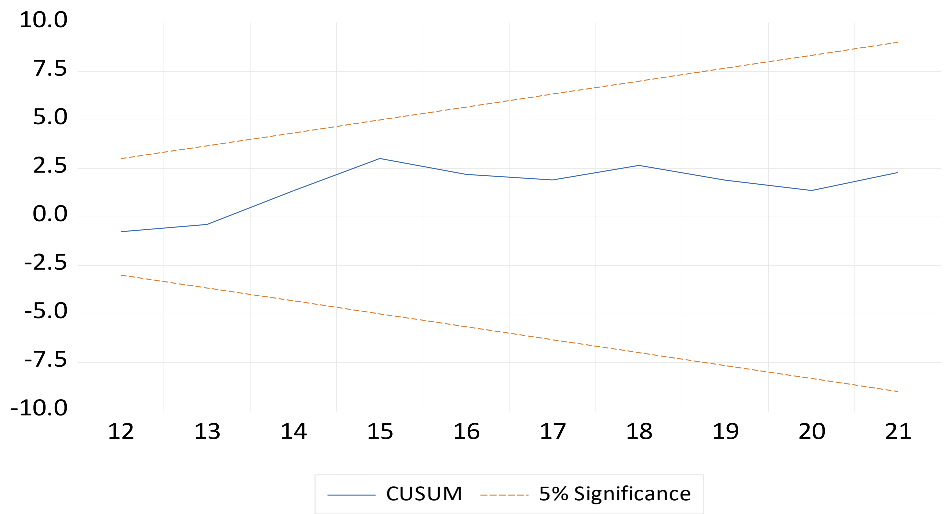

Figure 1: Cumulative sum of recursive residual (CUSUM)

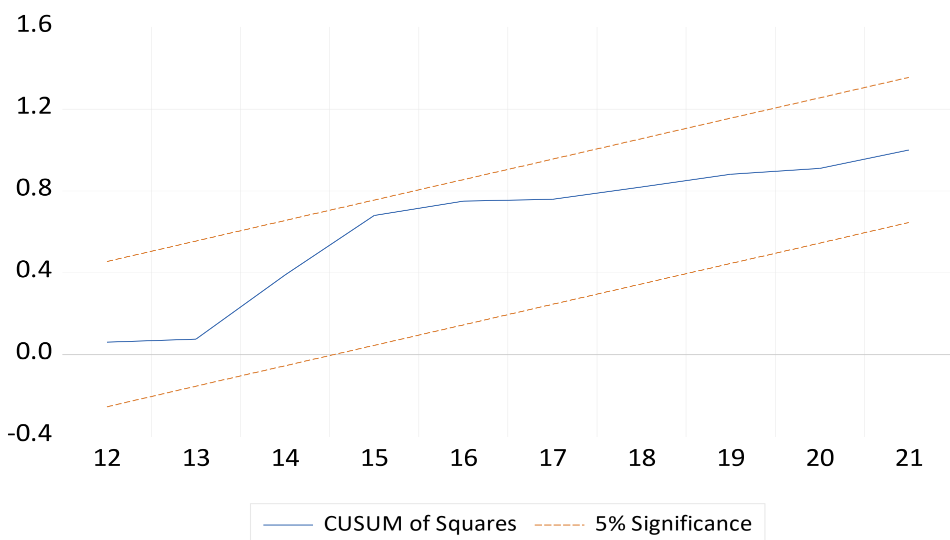

Figure 2: Cumulative sum of squares of recursive residual (CUSUMSQ)

Conclusions

The transition to Industry 4.0 presents both opportunities and challenges for Malaysia's skilled workforce. This study highlights several key findings regarding the impact of skilled workers on R&D amidst rapid technological change. High-skilled workers positively influence R&D expenditures in the positively influence R&D expenditures in the short term, emphasising their critical role in driving innovation and technological advancement.

However, their long-term impact appears less significant, possibly due to diminishing returns or insufficient investment in R&D infrastructure. Semi-skilled workers exhibit a negative relationship with R&D, reflecting the limitations of their technical expertise and the additional supervision and training required.

This suggests that merely increasing the number of semi-skilled workers may not lead to significant advancements in R&D. Foreign Direct Investment (FDI) positively affects R&D both in the short and long run, indicating that financial resources from foreign investments are crucial for supporting innovative activities and research initiatives.

Policymakers should prioritise reforms in the educational system to better align curricula with the skills required for Industry 4.0. This includes integrating advanced technology, critical thinking, and problem-solving skills into educational programmes to prepare students for future R&D roles. Government and private sector investments in R&D should be increased to create an environment where high-skilled workers can fully utilise their expertise.

This encompasses funding research projects, supporting innovative technologies, and improving R&D facilities. Strengthening partnerships between academic institutions and industry players is essential to ensure that research efforts are relevant and that academic research is effectively translated into practical applications. Such collaborations can also facilitate knowledge transfer and innovation. Additionally, developing and funding training programmes that focus on upskilling semi-skilled workers is crucial.

These programmes should aim to enhance their technical capabilities and reduce the need for intensive supervision, thereby improving their contributions to R&D activities. It is also important to continuously assess the evolving needs of the workforce in relation to Industry 4.0 technologies. This technological advancements and their impact on job requirements, and adjusting training and educational programmes accordingly.

By addressing these areas, Malaysia can better equip its workforce to meet the demands of Industry 4.0, enhance its R&D capabilities, and maintain its competitive edge in the global economy.

Acknowledgements

The authors would like to sincerely thank the Editorial Board and reviewers of the journal for reviewing and providing comments on the article's content.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest to disclose in relation to this research. All authors have made substantial contributions to the conception, design, execution, and analysis of the study and have approved the final manuscript.

References

Abowd, J. M., Haltiwanger, J., Lane, J., McKinney, K. L.,& Sandusky, K. (2007). *Technology and the demand for skill: An analysis of within and between firm differences* (Working Paper 13043). NBER Working Paper Series. Retrieved from http://www.nber.org/papers/w13043

Ahmad Sekak, S. N., Mohd Sazali, S., Nizam Akbar, A. R., & Md Junus, Y. (2022). Challenges and opportunities towards Industrial Revolution 4.0 (IR4.0) among contractors in Malaysia construction industry. *Jurnal Penyelidikan Sains Sosial (JOSSR),* 5(17), 42-49.

Aiyetan, O. A., & Dillip, D. (2018). System Dynamics Approach to Mitigating Skilled Labour Shortages in the Construction Industry: A South Africa Context. *Construction Economics and*

Building, *18*(4), 45-63. https://doi.org/10.5130/AJCEB.v18i4.6041

Basit, S. A., Kuhn, T., & Cantner, U. (2022). The role of market competition for knowledge competencies, R&D and innovation: An empirical analysis for German firms. *European Journal of Management Studies*, *27*(2), 229-253. https://doi.org/10.1108/EJMS-09-2021-0084.

Carpenter, F. (2017). The top 10 R&D scientist skills in high demand. https://www.biospace.com/top-10-r-and-d-scientist-skills-in-demand

Cordero, R. (1999). Developing the knowledge and skills of R&D professionals to achieve process outcomes in cross-functional teams. *The Journal of High Technology Management Research*, *10*(1), 61-78. https://doi.org/10.1016/S1047-8310(99)80003-0

Danial (2019). Malaysia's Industry 4.0 Main Challenge: Talent Shortage. Retrieved from https://www.ajobthing.com/resources/blog/malaysias-industry-4-0-main-challenge-talent-shortage

Díaz, G.A., Barge-Gil, A., & Heijs, J. (2020). The effect of innovation on skilled and unskilled workers during bad times. *Structural Change and Economic Dynamics*, *52*, 141-158. https://doi.org/10.1016/j.strueco.2019.09.012

Lee, N. & Clarke, S. (2019). Do low-skilled workers gain from high-tech employment growth? High-technology multipliers, employment and wages in Britain. *Research Policy*, *48*(9), Article 103803. https://doi.org/10.1016/j.respol.2019.05.012

Li, X., Wang, J., & Liu, X. (2013). Can locally-recruited R&D personnel significantly contribute to multinational subsidiary innovation in an emerging economy? *International Business Review*, *22*(4), 639-651. https://doi.org/10.1016/j.ibusrev.2012.12.002

Lucas, R.E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22*(1), 3-42. https://doi.org/10.1016/0304-3932(88)90168-7

Matricano, D. (2020). The effect of R&D investments, highly skilled employees, and patents on the performance of Italian innovative startups. *Technology Analysis & Strategic Management*, *32*(10), 1195-1208. https://doi.org/10.1080/09537325.2020.1757057

Otero, M.S., Brown, P., & Freebody, S. (2023). High skilled workplaces, technological change and employment: Can educational reform do it? *International Journal of Educational Research*, *122*, Article 102265. https://doi.org/10.1016/j.ijer.2023.102265

Padeli, W., Mustafa, W.A., Pangil, F., Kadir, K.A., & Dwita, V. (2024). Knowledge management and the Fourth Industrial Revolution (4IR): A Recent Systematic Review. *Journal of Advanced Research in Applied Sciences and Engineering Technology (ARASET).* 51(2), 18-33. https://doi.org/10.37934/araset.51.2.1833

Piva, M. & Vivarelli, M. (2009). The role of skills as a major driver of corporate R&D. *International Journal of Manpower*, *30*, 835-852. https://doi.org/10.1108/01437720911004452

Saka, H., & Orhan, M. (2022). R&D and Employment relation: Differences in low and and high-skilled employment in developing economies. *Eurasian Journal* *of Business and Economics*, *15*(30), 63-86. https://doi.org/10.17015/ejbe.2022.030.04

Sokhanvar, A. & Çiftçioğlu, S. (2022). The Impact of R&D on skill-specific employment rates in the UK and France. *European Review*, *30*(2), 151-171. https://doi.org/10.1017/S1062798720000010.

Wang, Y. (2024). How employees are affected by working in R&D-investing firms. *Industry and Innovation*, 1-25. https://doi.org/10.1080/13662716.2024.2420783

Yusoff, W.F.W., Yusob, J., & Mahdi, W.M.I.W. (2023). Exploring Impacts and Challenges Adopting Industrial Revolution 4.0 Among Manufacturing Small Medium Enterprises (SMEs) In Malaysia. *International Journal of Academic Research in Business and Social Sciences*, *13*(11), 1733-1757. http://dx.doi.org/10.6007/IJARBSS/v13-i11/19540