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Industry 4.0 Technology Adoption in Malaysian Manufacturing: Strategies for Enhancing Competitiveness

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ABSTRACT

New technologies related to the Fourth Industrial Revolution (IR 4.0) are driving changes in global value chains (GVCs). These changes are already impacting Malaysia which has been deindustrializing and losing its competitive advantage in labour-intensive manufacturing to neighbouring countries, which offer lower labour cost while they are quickly improving their infrastructure. While this is a general trend for Malaysia, a notable exception is the state of Pulau Pinang, which has maintained its industrial base and shifted towards high-technology manufacturing. The research findings suggest that IR 4.0 technology adoption are used to improve productivity and quality, and rely on close collaboration with local technology suppliers. The development of local technology suppliers is an area in which Malaysia can move up to higher value-added activities within the GVC, including R&D and design. Importantly, workers are generally receptive to IR 4.0 technologies, as it improves the quality of their work. However, these technologies can also reduce employment for low-skilled repetitive work, which is an area in which Malaysia's manufacturing competitiveness is already declining. To achieve successful IR 4.0 technology deployment, manufacturing firms need government support, especially in the area of skills and training, both to upskill current workers, and to ensure new workers have the right educational foundation. Training programs initiated by industry, but funded by government, appear to be successful in addressing some of the skills gaps. Viewed more broadly, the improving quality of work and increased productivity due to IR4.0 technology adoption, could play a role in making small- and medium-sized manufacturers more attractive as employers. This would help them hire and retain skilled Malaysian workers, who might otherwise opt to work for multinationals, or overseas.

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Executive Summary

New technologies related to the Fourth Industrial Revolution (IR 4.0) are driving changes in global value chains (GVCs). These changes are already impacting Malaysia, which has been deindustrializing and losing its competitive advantage in labour-intensive manufacturing to neighbouring countries, which offer lower labour cost and have been quickly improving their infrastructure. At the same time, the shift towards higher value-added manufacturing activities has been limited, leading to what researchers call “premature deindustrialization”, whereby a country’s industrial base declines before it becomes a high-income economy. While this is a general trend for Malaysia, a notable exception is the state of Pulau Pinang which has maintained its industrial base and shifted towards high-technology manufacturing. Therefore, Pulau Pinang is an interesting case study of how IR 4.0 technologies can be successfully adopted within the Malaysian context.

To investigate these questions, qualitative interviews supported by detailed quantitative survey of manufacturers in Malaysia was performed to examine the technology adopted, skills and talent and industrial performance of the manufacturing sectors.

Our research findings, which includes many Pulau Pinang-based manufacturers, suggest that IR 4.0 technology adoption are used to improve productivity and quality, and rely on close collaboration with local technology suppliers. The development of local technology suppliers is an area in which Malaysia can move up to higher value-added activities within the GVC, including R&D and design. However, manufacturers did not use these technologies to diversify to these activities. The position of the manufacturing firm in the GVC matters when it comes to the decisions on technology adoption - MNCs generally follow the decisions at the headquarters, while many local manufacturers rely on the requirements of the lead firms.

Importantly, workers are generally receptive to IR 4.0 technologies, as it improves the quality of their work. However, these technologies can also reduce employment for low-skilled repetitive work, which is an area in which Malaysia’s manufacturing competitiveness is already declining. Indeed, we have observed that task contents have been changing in jobs when technology adoption are available.

By far, we identified that the availability of talent, skills and continuous training as the major challenge to IR 4.0 technology adoption in Malaysia, although several successful industry-led training initiatives have been launched. This is especially so for SMEs, where they face competition from MNCs in hiring talents. Skills-training becomes a crucial solution for the manufacturing sector, however it remains at the level of simple training in using digital tools. The lack of training to build a digital-first mindset plus the outsourcing of training to technology providers will put the manufacturing firm at risk for not building internal talent to successfully and effectively adopt IR 4.0 technology.

To achieve successful IR 4.0 technology, manufacturing firms need to work closely together with governments, especially in the area of skills and training, both to upskill current workers, and to ensure new workers have the right educational foundation. Training programs initiated by industry, but funded by government, appear to be successful in addressing some of the skills gap. Viewed more broadly, the improving quality of work and increased productivity due to IR4.0 technology adoption, could play a role in making small- and medium-sized manufacturers more attractive as employers. This would help them hire and retain skilled Malaysian workers, who might otherwise opt to work for multinationals, or overseas.

Introduction: Technology adoption and IR 4.0 & manufacturing

Industrial revolutions (IR) in the manufacturing industry have historically been associated with episodes of fast output growth and accompanied by national socioeconomic progress (Hubert Backhaus and Nadarajah 2019). Mechanization and steam power in the first IR, assembly lines for mass production in the second IR, and automation in the third IR have transformed traditional manufacturing into large-scale industries, revolutionized factory systems, and generated various strata of job opportunities while increasing production. This increased productivity and industrial growth at the firm and sector level impacts the economic growth of nations. We are now experiencing the fourth IR (IR4.0)[1], which introduces smart factories and Artificial Intelligence in the manufacturing industry, with new competitive challenges for business leaders and policymakers. Overcoming those challenges to stay ahead of competitors and move up in the value chain (GVC) ladder will be crucial for the long-term economic success of all countries, including Malaysia.

Historically, in low- and middle-income countries, a positive relationship has been found between the growth of manufacturing output and overall GDP growth (Szirmai and Verspagen 2015). Manufacturing has long been seen as an engine of broader economic growth and countries that are quick to adopt and adapt to the IRs, can more easily position themselves on top of GVCs. In this report, we argue that Malaysia is at a crossroad: it is increasingly challenged by competition from other labour abundant countries (particularly in Asia) without yet being able to fully break through the higher value-added activities characteristic of the IR 4.0. A successful adoption of IR 4.0 will be a key ingredient between a “low road” (low margin commoditized production, labour abundant) development pathway, versus a high road (knowledge intensive, generator of well-paying jobs). As we detail in this study, the growth of Malaysia’s manufacturing sector has relied on a steady stream of unskilled and low-skilled foreign labour in the past decade. However, in an age of highly mobile capital, labour abundant industries can easily move to other countries. For Malaysia, this threat could come from relocation to nearby nations in South and Southeast Asia with lower wages (Chandran and Devadasan 2017).

If wages alone cannot be Malaysia’s key competitive factor for long-term and sustainable growth, the country is also lagging others in technology adoption, as some Asian countries, such as China, have a high degree of IR4.0 deployment. It is therefore crucial for Malaysia, in order to maintain or increase its competitiveness in the manufacturing sector, to pay attention to the strategic adoption of IR4.0 - and policy and government-led initiatives can play a key role.

The socioeconomic impact of IR4.0 is also an important reason for government and policy makers to pay attention to IR4.0 adoption. The introduction of robotics, analytics, and smart technology on the shop floor is believed to reduce the number of workers and in turn reduce job opportunities. Besides, the jobs that are opened require new skills, which calls for upskilling policies for the existing workforce. There is a need to understand how job descriptions and tasks assigned to humans evolve in tandem with IR4.0 adoption, how this evolution increases the demand for skilled workers and talent, and what the education sector, industry and the government must do to equip the incoming workforce. Altogether, there are important concerns as to whether IR4.0 adoption puts people out of work.

[1] “Industry 4.0 is understood as a new industrial stage in which there is an integration between manufacturing operations systems and information and communication technologies (ICT) – especially the Internet of Things (IoT) – forming the so-called Cyber-Physical Systems (CPS)” (Dalenogare et al. 2018)

This study addresses these questions about IR4.0 adoption in the Malaysian manufacturing industry through semi-structured interviews conducted with manufacturers (technology adopters) and solution providers (technology providers) in the country. The fifty companies interviewed were from manufacturing sub-sectors which included food and beverage, textiles, aviation, electric and electronics, medical devices, plastics, rubber, automotive, and petrochemicals. Questions covered the following areas: description and history of the company; product manufactured; adoption of technology (motivation, challenges, risks, other factors); impact of technology; technology and work/workers; external environment; COVID-19 impact; and IR4.0-related grants.

The interviews took about one hour for each session and were conducted with owners, senior management-level employees and engineers of Malaysian manufacturing companies. We followed a questionnaire and research methodology jointly developed with research partners from USA (MIT), Brazil (UFRGS and CNI), and Turkey (Koç University and MESS), leading institutions in each country. The research team also did an extensive literature review on understanding technology, economic development and the work of the future. Other interviews in Malaysia were conducted with public stakeholders from international organizations, federal and state governments of the country, and independent agencies.[2]

The qualitative interviews are also supported with a detailed quantitative survey of manufacturers in Malaysia.[3] This includes the examination of the technology adopted, skills and talent and industrial performance of the manufacturing sector. The quantitative survey is used to support the findings from the qualitative interviews, which are rich in details and contextual challenges faced by firms in Malaysia.

Key topics and takeaways explored, based on primary data collection and literature review, include:

- The need for investing in talent and skills upgrading to fully benefit from the advances of manufacturing technology
- Suggested pathways to talent and training in preparation for the work of the future
- Changes in job description and tasks as a result of IR4.0 adoption
- The type and nature of the different technologies adopted
- Determining factors and motivation for adopting technology in Malaysia
- Developing best-matched/best-fit government incentives to encourage IR4.0 adoption
- State-led initiatives through a New Industrial Policy

This report is structured as follows. Part I provides the context of the manufacturing sector and the GVC. Part II gives a brief description of the history of manufacturing in Malaysia. Part III takes a closer look at Pulau Pinang the biggest national exporter of electric and electronic parts. It is also a state that is still heavily industrial, unlike other parts of Malaysia, which have been

[2] These include the Ministry of International Trade and Industry (MITI), Ministry of Economic Affairs, The Office of the Minister of Science, Technology, and Innovation (MOSTI), Malaysian Productivity Corporation (MPC), SME Corporation, Malaysian Investment Development Authority (MIDA), MIMOS Malaysia, Malaysian Industrial Development Finance (MIDF), Academy of Sciences Malaysia, Selangor Human Resource Development Center (SHRDC), Malaysia International Labour Organisation (ILO), Penang Skills Development Center (PSDC), Invest Penang, and Penang Institute.

[3] The quantitative survey was fielded between November 2021 and November 2022 and outsourced to a survey company, using a stratified random sampling of medium and large firms across Peninsular Malaysia. The overall response rate (n=62) was below what would be needed for robust statistical analyses. Therefore, we use this data as secondary to the main analysis provided by the qualitative work.

mentioned as a case of premature deindustrialization. Part IV is a showcase of the results from the study and Part V is a discussion of the results. Part VI provides policy recommendations.

PART I: Manufacturing sector and the global value chain

Since the 1990s, there has been a confluence of factors that shaped a new global division of labour. Lower transportation costs (such as the expansion of container shipping), advances in information technology and the internet, and trade agreements, among other factors, helped to reduce the transaction costs involved in relocating activities to where they can be done most productively. By fragmenting production into different tasks and components which can be manufactured in different sites across the world, firms have been able to exploit local competitive advantages and thus reduce costs and increase innovation capabilities. This spatial reorganization of production has generated the rich academic literature of GVCs, which we use as an analytical framework in this study.

The continued evolution of firms operating in GVCs towards higher productivity and efficiency to drive growth is seen across many business sectors, but particularly in the manufacturing industry. This shift has complex outcomes for **national public policies, standards of industrial performance and workers.**

First, the emergence of GVCs reduced the barriers of entry for countries to participate in global trade. Instead of having to master the capability of a whole industry - for example, the automotive industry - a country can be a significant exporter of a small segment of this global industry. This means that even countries with relatively poor infrastructure and underdeveloped human resources can find a niche where they can plug into the GVC of lead firms. This is both an opportunity (for countries which are not part of GVCs) and a threat (for those who currently are and can face new competitors).

As a consequence, and a second point worth highlighting, the key challenge of today’s economy is not necessarily participating in GVCs, but to ascertain where one stands in it – in other words, how much value is generated domestically. It is critical for policymakers, business leaders, and workers to consider upgrading strategies to drive growth and quality of life improvement. Key determinants of countries' participation in the GVC include factors such as geography, availability of natural resources, market size, and level of development. Some of these characteristics, such as geography, are fixed while others are variables that can be shaped by good policy arrangements. In terms of firm related factors, high labour productivity, large firm size, foreign ownership, and high technological capabilities have been cited as key factors that empower small and medium enterprises (SMEs) to participate in the GVC and increase the value of said participation (Urata and Baek 2020).

Third, it is important to identify where most value is generated across a value chain and what levers can be deployed to tap into higher value-added activities. A helpful visual guide to that is the Smile Curve, a concept coined by Stan Shih, founder of the IT manufacturer Acer. It provides a visual depiction of how value is generated across different activities in a value chain. It is highest in upstream and downstream activities like R&D, design, services, and marketing. It is lowest in tasks that can more easily be replicated and outsourced to contract suppliers, like logistics and production, as is shown in Figure 1 (Dünhaupt et al. 2022).

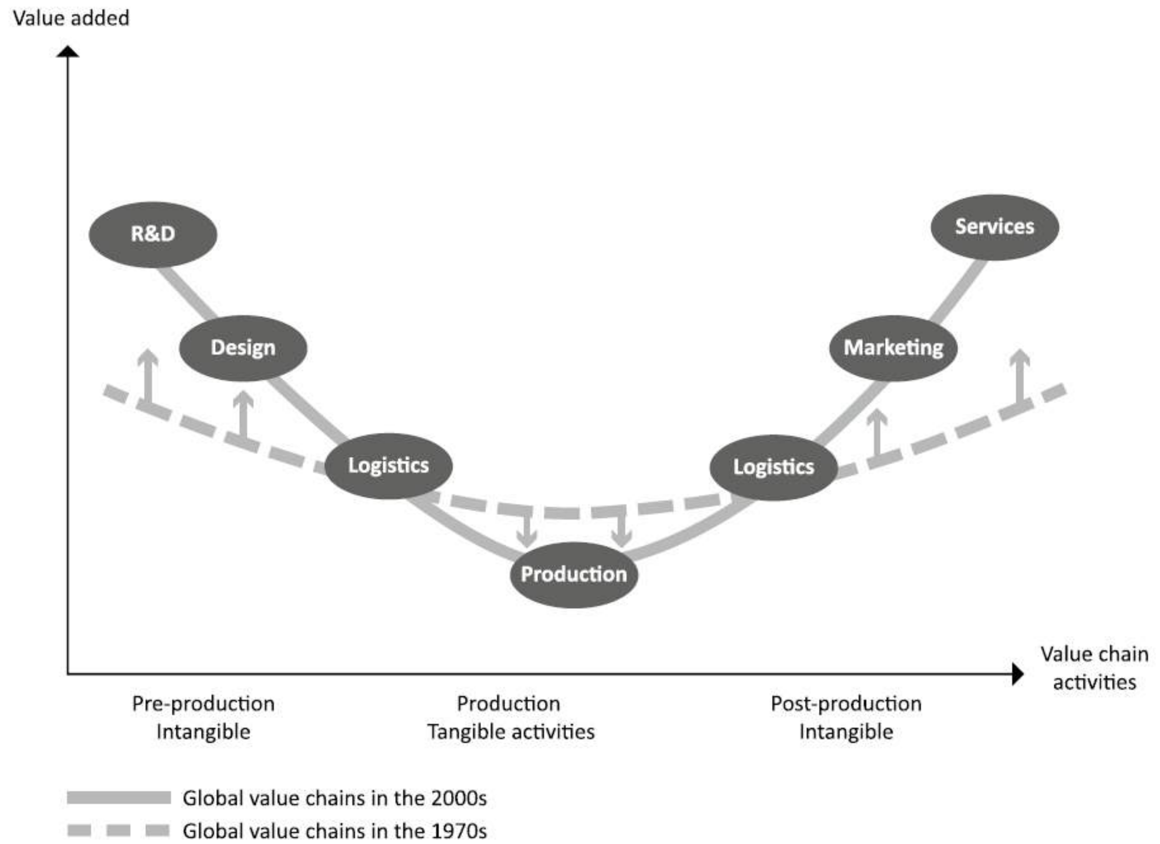


Figure 1: The Smile Curve (Source: Dünhaupt et al. 2022, adapted from OECD 2013)

Understanding where most value is generated in GVCs is an important step in identifying how to devise strategies to upgrade one's position within a value chain. In addition to state-actors and their country-level policies, lead firms are key actors in deciding where to locate production facilities, how much knowledge is shared with suppliers, what opportunities they have to participate in higher value-added activities, etc. These critical decisions are part of the governance of GVCs. Scholars have devoted attention to understand and characterize the ways in which firms in different countries interact and shape their GVCs (Gereffi, Humphrey, and Sturgeon 2005). By characterizing GVC governance, we can understand the different types of inter firm power relationships that exist and how this can determine the value chain coordination between buyers and suppliers. The power dynamic between firms can continue to evolve based on other key factors such as supplier competence, complexity and codification of transactions, firm characteristics such as size and capabilities as well as external factors such as changes in the market such as customer demand or technologies (Gereffi, Humphrey, and Sturgeon 2005; Buckley 2011). Other factors that can shape GVC configuration include geographic scope such as degree of globalness and coordination of actors and operation modes in the value chain (Gereffi and Stark 2016).

These factors, among many others (Hernández and Pedersen 2017) can determine interfirm power relationships and how and why firms and countries may advance or fail in the global economy. Whilst our report does not explicitly investigate how IR 4.0 technology adoption is shaping GVC configuration for the manufacturing sector in Malaysia, the GVC remains a key component that could determine a firm or countries' motivation to automate.

Malaysia is well integrated into the GVC value chain, with a manufacturing industry focused on backward linkages (final stages of the production process), and a high import of 43% into its export products. Malaysia's degree of backward linkages highlights its focus in the end stages of the GVC (Lim and Tng 2017). More recent research has noted Malaysia's experience of premature deindustrialisation since the 1990s, characterized by a reduction in GVC participation in the manufacturing and services industry (C. Lee 2020; 2022). Within the manufacturing sector, the electronics industry which contributes to a significant portion of Malaysia's GDP, as highlighted above, faced a decline in GVC participation.

The failure of the manufacturing sector to upgrade has been attributed to Malaysia's high reliance on foreign investment in the manufacturing sector that have continued to focus on low value-added production as well as manufacturers' continued reliance on low skilled, cheap foreign labour (Bank Negara Malaysia 2017).

Digital technology, currently through IR4.0 technologies, can add value and help countries upgrade their position in the GVC (economic outcomes) and for their workers (social outcomes). Economic upgrading could mean using technology to move towards high value-added activities by improving productivity and growth or the value or sophistication of the product they sell (Humphrey and Schmitz 2002). This has potential social consequences specifically for the evolution of work and how manufacturing companies design their business model.

We use the insights from how productive structures are geographically reallocated and challenges faced by firms in upgrading their goods, services, and processes, from the GVC literature, as an analytical reference point. This will guide the discussion that follows which will address the history of manufacturing in Malaysia, and in Pulau Pinang, and the interpretation of the empirical material collected from fieldwork.

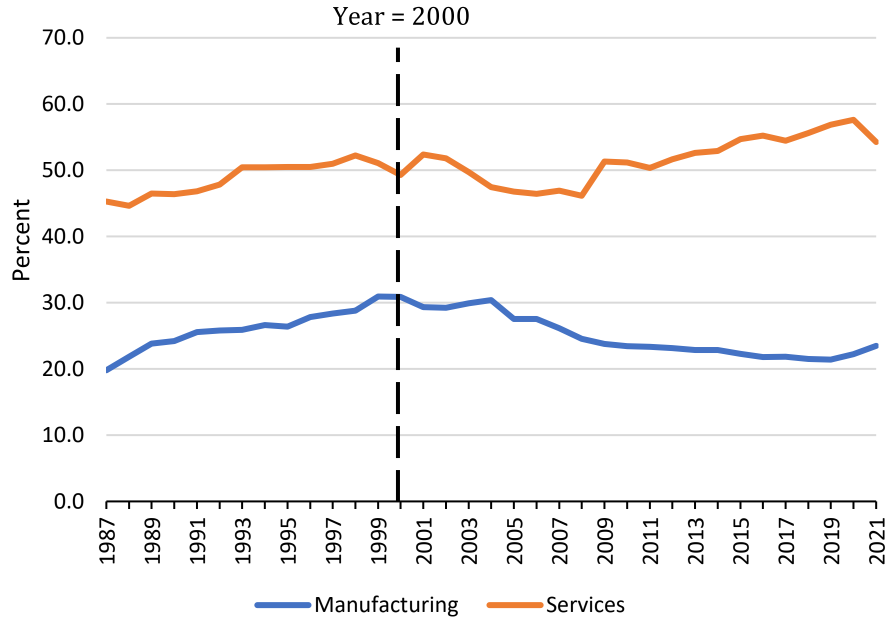
Part II: History of the Manufacturing Sector in Malaysia

Malaysian manufacturing – ladder to development

Malaysia is an important node within the global manufacturing value chain, especially in sectors such as electronics manufacturing. Since the 1980s, the manufacturing sector in Malaysia remains the major driver for economic growth and employment in Malaysia. This growth followed the Promotion of Investment Act 1986, encouraging foreign investments into Malaysia and turning Malaysia into one of the major manufacturing centres in the world, while moving away from an import-substitution industrialisation to an export-led industrialisation (Jomo 2013).

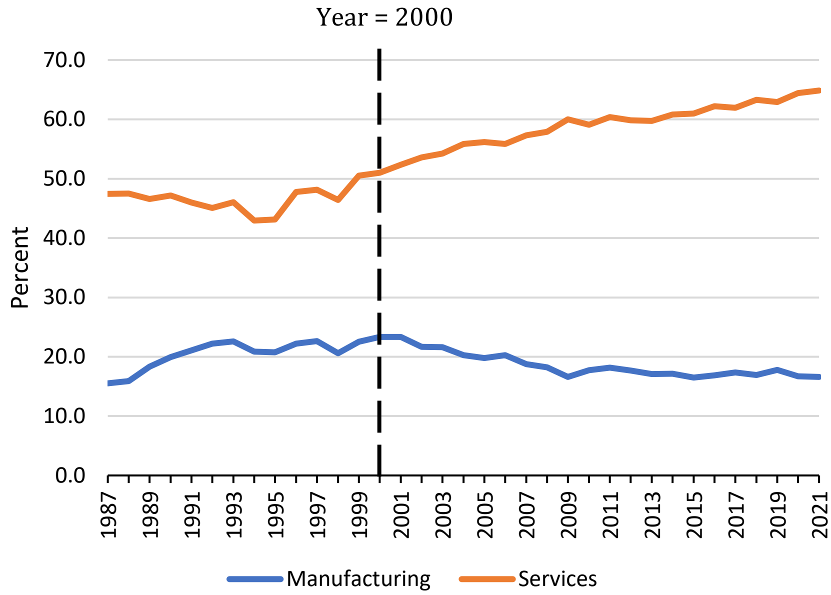
The share of the manufacturing sector increased from around 20% of GDP in 1987 to 31% in 2000, while the share employment in the manufacturing sector also increased rapidly from 15% in 1987, to 23% in 2000. However, while Malaysia remained an upper-middle income country, the share of manufacturing GDP has since fallen to 21% in 2019 (Figure 1), while the employment share of the manufacturing sector has also fallen to 17% in 2019 (Figure 2). During the COVID-19 pandemic, the share of GDP for the services sector fell while the share of GDP for the manufacturing sector increased to 23% in 2021, possibly due to the higher demand for medical products and devices during the COVID-19 pandemic, while the share of total employed in manufacturing remained around 17%.

Figure 2: Share of Manufacturing and Services sector GDP per total GDP, 1987 - 2021



Source: Department of Statistics Malaysia, Authors' Calculation

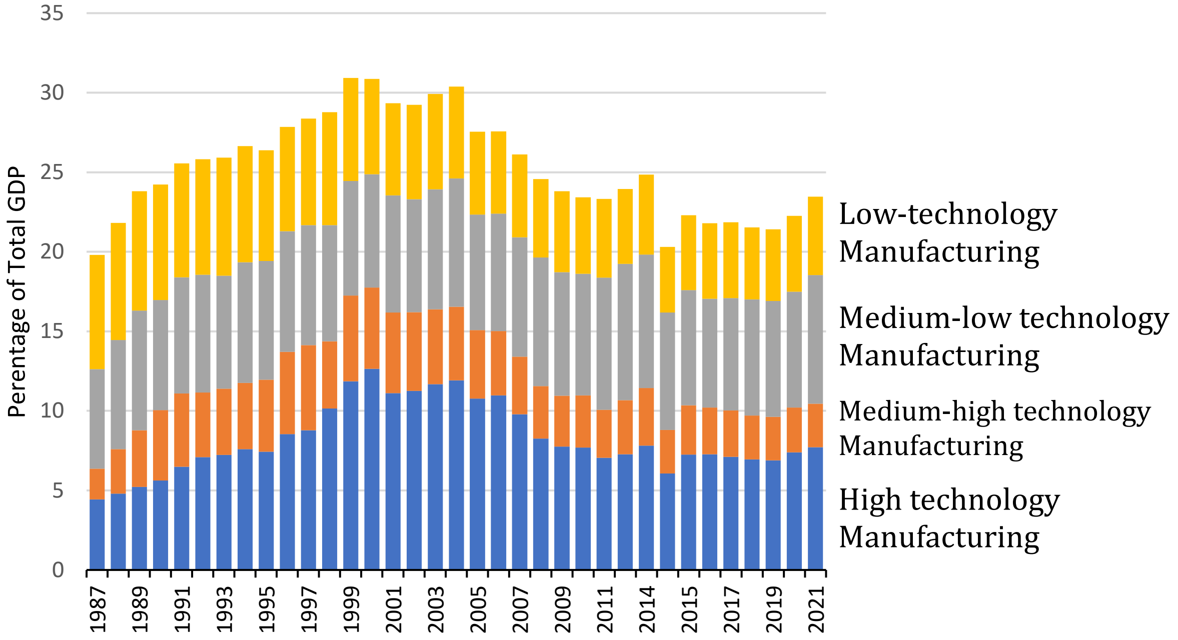
Figure 3: Share of Manufacturing and Services sector per total employed, 1987 - 2021



Source: Department of Statistics Malaysia, Authors' Calculation

The profile of the share of manufacturing subsector of the GDP is dominated by a few subsectors, namely, the electronics, chemicals, and refined petroleum products subsector. This is mainly driven by export-led manufacturing subsectors - electronic integrated circuits alone occupy 22.1% of total export value for Malaysia in 2019 and refined petroleum at 5.5% (The Atlas of Economic Complexity). When categorized by technology intensity, the share of GDP for high-tech manufacturing industry (which includes electronics manufacturing) over total manufacturing GDP increased up to 35% in 2000, reducing to roughly 32% in 2021 (Figure 3). When categorized by technology intensity, the share of GDP for high-tech manufacturing industry (which includes electronics manufacturing) over total manufacturing GDP increased up to 35% in 2000, reducing to roughly 32% in 2021 (Figure 3). In comparison, medium-low manufacturing industries (which includes refined petroleum products) increased up 35% in 2021.

Figure 4: Share of Manufacturing GDP by technology intensity per total GDP, 1987 - 2021



Source: Department of Statistics Malaysia, Authors' Calculation

The manufacturing sector seems to be increasingly driven by mid-technology intensity subsectors, such as commodities-based refined petroleum subsector, while the share of high-technology intensity subsector has fallen since 2000. Indeed, there are some indications that the availability of cheap foreign workers has led to lower investments into technology (Ng, Tan, and Tan 2018) - potentially leading to the slow-down in upskilling workers for high-technology intensity subsectors. This poses a particular risk to the future growth of the Malaysian economy, where Malaysia may increasingly compete in the lower technology intensive, lower value-added manufacturing subsectors.

Large manufacturing firms dominate the landscape

Table 1: Distribution of Manufacturing Firms in Malaysia, 2021

Size of Manufacturing Firm		**Manufacturing Establishments in Malaysia**	**Share of Establishment by Size (%)**	**Number of Employees**	**Share of Employees by Establishment Size (%)**
Micro	Fewer than 5 Employees	18197	37.06	44533	2.10
Small	5 - 74 Employees	25921	52.79	480963	22.70
Medium	75-200 employees	3083	6.28	367392	17.34
Large	201 employees and above	1900	3.87	1226270	57.87
Total		**49101**	**100**	**2119158**	**100**

Source: Department of Statistics Malaysia, Authors' Calculation

In 2021, there were only 3.9% of manufacturing firms which were large firms, but these firms employ up to 57.9% of all manufacturing workers and 70.2% of total manufacturing value-add (Department of Statistics Malaysia, n.d.). Around 37.1% of firms had fewer than 5 employees, occupying 2.1% of all workers in manufacturing firms and only 0.7% of total value add. Around 52.8% of firms were small firms, occupying 22.7% of total share of manufacturing employees and 13.3% of total manufacturing value-add.

The average size of employees per firm of the manufacturing subsectors also differs greatly from each other - manufacturing firms for watches and clocks have on average 814 employees while customized tailoring, musical instrument manufacturing and "keropok lekor" (fish paste crackers) manufacturers have 7 or fewer workers on average.

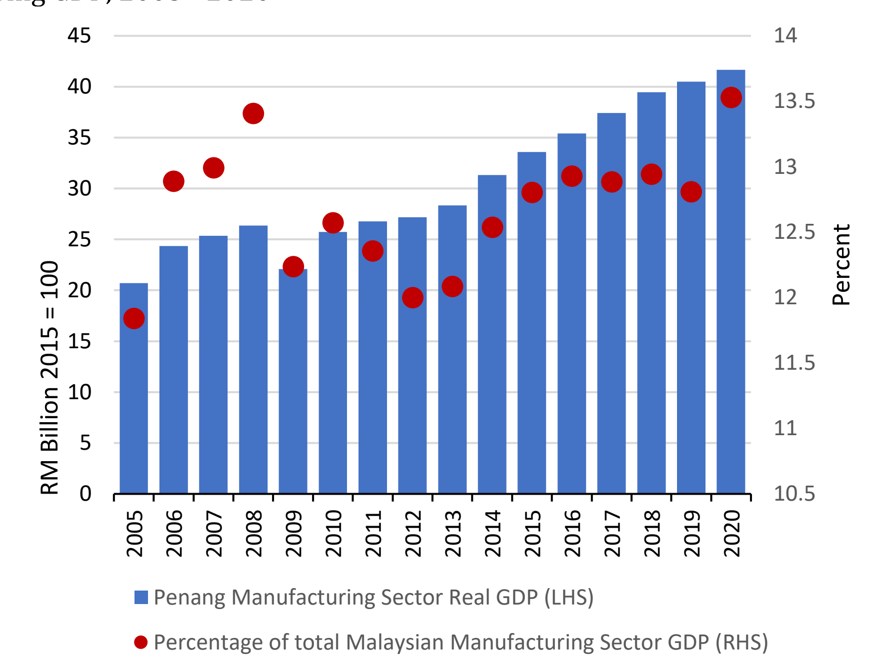
The Malaysian government has recognised the need to enable greater technology upgrading to secure and improve Malaysia's role in the GVC. Thus, the Industry4WRD policy, which is the national policy on Industry 4.0 adoption was introduced in 2018, together with the 11th Malaysian Plan (2016 - 2020). The policy includes soft loan scheme for automation and modernisation, matching funds for technology adoption, capital allowances and others. While some news reports have indicated that the program has achieved its target, however, there has not been publicly available detailed reporting on the performances in these policies. Details for the policies are found in Appendix 1.

PART III: Development of the Pulau Pinang Manufacturing Sector

General Overview

The state of Pulau Pinang is an important base for manufacturing in Malaysia. Since the 1980s, the state of Pulau Pinang has proactively carried out industrialization outreach programs to attract foreign investment through its master plan for growth. By the mid-80s, Pulau Pinang had 8 free trade zones, and had a fast-growing semiconductor industry (Rasiah 1995). Its manufacturing industry saw a growth from just 36 companies in 1971 with total employment of 4,500 to 243 companies in 1983 with total employment of 57,600 (Rasiah 1995). Its importance continues to be shown today, where the total number of manufacturing companies is at 6734 as of June 2022 (DOSM) and contributes to 13.5% of the total manufacturing real GDP nationally, second behind the state of Selangor in 2020 (Figure 4).

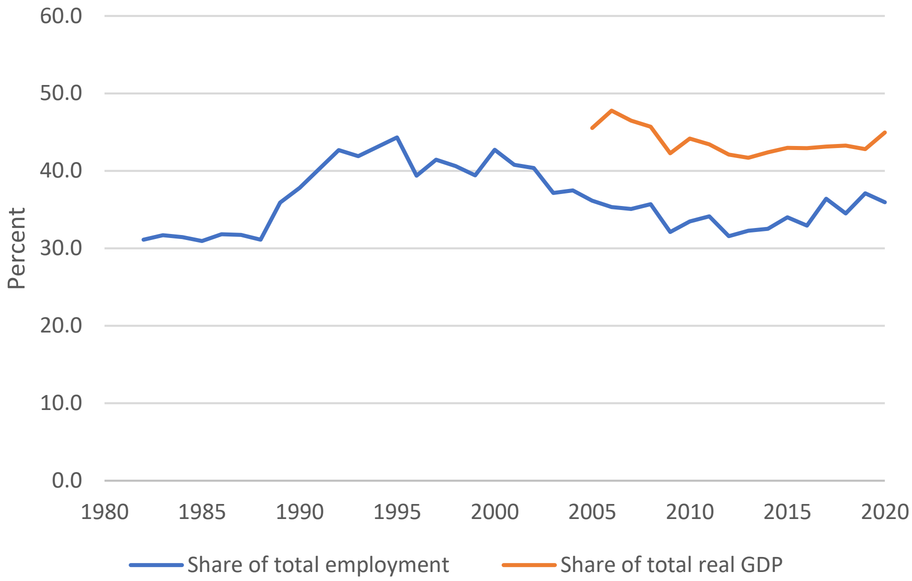
Figure 5: Real Pulau Pinang Manufacturing Sector GDP and percentage of total Malaysia manufacturing GDP, 2005 - 2020



Source: Department of Statistics Malaysia, Authors' Calculation

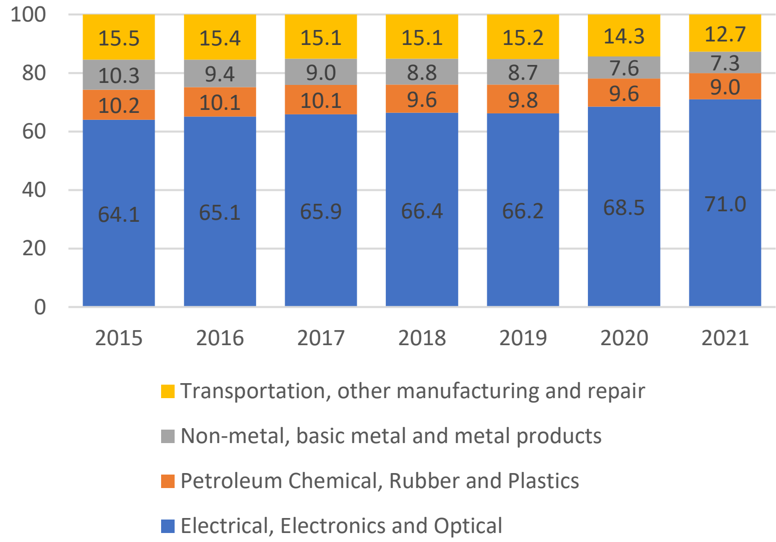
While Malaysia has undergone premature deindustrialisation since 2000, the state of Pulau Pinang has not undergone similar trends. The number of workers in the manufacturing sector has increased from 119 thousand workers in 1982 to nearly 300,000 workers in 2020, and the percentage of total employed in the manufacturing sector increased from 31% of total employed in Pulau Pinang in 1982 to 35% in 2020 (Figure 5), while the share of manufacturing real GDP over total real GDP has not shown the declining trend seen nationally. Both these trends highlight the importance of the manufacturing sector in Pulau Pinang and serve as evidence that this state is not suffering from premature deindustrialisation. Similarly, unlike the declining national share of high-technology intensity manufacturing subsector, the share of electrical, electronics and optical subsectors has increased from 64.1% in 2015 to 71% in 2021 of the total share of Pulau Pinang state manufacturing GDP (Figure 6).

Figure 6: Manufacturing sector share of employed and real GDP of the Pulau Pinang, 1982 - 2020



Source: Department of Statistics Malaysia, Authors' Calculation

Figure 7: Share of manufacturing subsector per total Pulau Pinang manufacturing sector GDP, 2015 - 2021



Source: Department of Statistics Malaysia, Authors' Calculation

As shown above, the electrical and electronics subsector plays a crucial role in the Malaysian manufacturing sector - nearly 40% of all Malaysian export value comes from electrical, machinery and equipment ("The Atlas of Economic Complexity" n.d.). Pulau Pinang plays an extremely important role: housing 3 of the global top 10 semiconductor leaders by sales, Pulau Pinang's electrical and electronics sector export value is around 60% of the total Malaysian electrical and electronic export value (InvestPenang n.d.) 23% of Malaysia's total manufacturing investment FDI in 2019 to 2020 was also directed to Pulau Pinang. The main manufacturing products of focus in that state are the integrated circuit (IC) and integrated circuit test design, back-end semiconductor, outsourced semiconductor assembly and test (OSAT) & electronics manufacturing services (EMS), optoelectronics, storage, medical technology, and front-end and back-end equipment manufacturing (InvestPenang n.d.).

The factors influencing Pulau Pinang avoiding deindustrialisation compared to the national economy warrants a closer look, especially with the consistent importance of the high-technology intensive electrical and electronics subsector that is potentially at the frontier of adopting IR4.0 technologies. This also highlights the importance of the different agencies in developing the high-tech intensity manufacturing sector. Agencies such as InvestPenang and Malaysian Investment Development Authority (MIDA) have consistently brought in investors and companies into Pulau Pinang, fostering greater investment and adoption of technology. However, what is more crucial is the need to establish talent and skills which in preparation for the present and future of the manufacturing sector. An important institution that was established between the industry, state government and academia is the Penang Skills Development Center (PSDC n.d.). PSDC was originally established in 1989 to train school-leavers and equip them as incoming workforce into the manufacturing industry and has more recently served as the center of excellence for Industry 4.0. The Penang Science Cluster (PSC) was set up with cooperation between the industry and the state government to encourage interest in STEM amongst school students and to ensure a healthy pipeline of future talent for the state.

Key challenges in attracting talent and skills

While the high-technology intensity manufacturing sector continues to grow in Pulau Pinang, talent and upskilling remains as the biggest challenge in limiting the sector. A study on workforce in Pulau Pinang by the Penang Institute in 2018 reported that 27.3% of high-tech manufacturing employers say that fresh graduates were not well-equipped for the positions offered, including a lack of meeting hard skill requirements, having poor command of the English language, and a lack of “maturity” (Penang Institute 2017). This study also showed that roles requiring the most improvement in high-tech manufacturing were engineering positions which required future skill sets in preparation for the adoption of cloud computing, big data, and artificial intelligence. In a 2014 survey (Haron, Junaimah, and Lim 2014) on 350 Pulau Pinang-based engineers, 86.4% of which were bachelor’s degree holders, found that job satisfaction, social welfare, pay, and security were not factors in choosing to migrate for work - which are some of the key factors usually associated with the “brain drain” phenomenon.

PART IV: Results

While Malaysia as a whole shows signs of premature deindustrialisation, we have seen that Pulau Pinang has been successful in avoiding such fate. However, IR 4.0 technologies have a disruptive potential and bring new challenges for firms and countries to maintain, and hopefully upgrade, their position within GVCs. Thus, this study investigates how the arrival of such bundle of technologies is impacting the local manufacturing sector.

The discussion of results looks at key themes from the 50 interviews conducted with likely adopters of IR4.0 technology and technology providers in understanding the nature and impact of IR4.0 technology in Malaysia[4]. These are summarized in Table 2 below and explored in detail in the rest of the section. The themes are then illustrated with selected quotes from company representatives. We disclose the sectors where these companies operate but their names have been anonymized, following best practices in research methodology to remove potential biases.

Table 2: Key Findings

Key Findings		**Summary**
Technology Adoption and the **Workforce**	Labour-replacing or labour-augmenting: Effects of technology on workers	• **Task content are changing** as IR 4.0 technologies are adopted - with new jobs being created. • **Upskilling of workers is needed** to use and operate IR 4.0 technologies, while some level of job reassignment but few cases of reducing employment. • Firms observed that their workers seem to accept the changes in technology and upskilling, which can prepare workers for the future. • Firms also observed that the **quality of work and safety has increased with IR 4.0 technology**. • Labour-augmenting approaches seem to dominate compared to labour replacement.
	Talent and skills - gaps and opportunities	• Firms report that talent and skills are the major challenge to IR 4.0 technology adoption. • **SMEs report difficulty in competing with MNCs** and neighbouring countries in hiring talent due to wages and other factors. • Lack of talent poses the risk of underutilisation of technology. • Most firms use upskilling as a solution, **but mainly simple training in using digital tools**, partly due to technology providers aiming to create easy-to-use interfaces. • **Fewer firms train workers to create a digital-first mindset**, missing out in creating long-term growth by

[4] The qualitative interviews were performed between July 2020 to June 2022, each of the interview taking around one hour each.

		retaining internal capacity to train and retain knowledge.
	Labour-intensiveness & foreign workers	• Technology adoption and foreign workers are not mutually exclusive, however there will be **less incentive to upskill foreign workers** due to their temporariness. • Potential rise in cost of hiring foreign workers and signalling from tightening government policies in foreign workers are **driving technology adoption to reduce foreign-worker dependence**.
IR4.0 in **Malaysian manufacturing:** motivations, adoption, and challenges	Digital technology adoption strategies	• **IoT platforms and sensors** are the most frequently adopted technology as a result of the desire for data and the growing awareness of the importance of data in improving the manufacturing processes. • **Cloud services** also serve as another base technology which is frequently adopted. The main adoption comes from serving as a database of different sensors. • Fewer Malaysian manufacturers mention of big data analysis and AI adoption • Other technologies used include computer planning and Product Lifecycle Management (PLM), Automated Guided Vehicles (AGVs) and Remote-controlled robots, automated advanced inspection and quality control
	Technology customisation and relationships with providers	• **Customisation of manufacturing processes together with vendors** are the most common, seen across small, medium, and large firms. This is due to the inherently unique requirements of each manufacturing process. • Technology adopters may want control over the customisation to preserve the ability to be flexible. Technology providers see this as an opportunity for collaboration. • Internal customisation was reported by large companies. • Some internal teams developed capabilities to the point of **spin-off companies**
	Global Value Chain and technology adoption in Malaysia - Global motivations	• A large portion of the global literature on drivers of industrial upgrading suggests that developing country suppliers' motivation to upgrade is determined by the buyer firms based in advanced economies • **MNCs which are integrated globally** were found to have the power to determine whether local branches **are able to choose which technology to adopt** and from which technology suppliers • Some lead firms require Malaysian manufacturers **to meet existing standards which the lead firms require** in a relational or modular governance - where the lead firms are in constant communication with the supplier to meet required standard.

		• Most of the Malaysian manufacturing sector comprises mostly second or third tier suppliers, **and are companies producing at high volume but for low complexity products and are labour-intensive**, which does not give these companies much of an impetus to automate. • Some companies show a drive to adopt technology despite no direct push by an outside lead firm.
	Industrial performance - motivations and challenges	• Industrial performance as motivation for tech adoption: i increase efficiency ii improve productivity iii improve quality control iv increase sales output & revenue v reduce capex and scale of workforce while maintaining/improving revenue & productivity vi reduce physical space needed for operations • Challenges faced in tech adoption: i **lack of understanding**, and uncertainty as to whether IR4.0 adoption would benefit the company ii processes that are **not traditionally automated** iii shortage of appropriate manpower to **maximize the benefits of the data generated** from the machines
Government incentive for IR4.0 adoption	Government incentives: Building capacity	• **Incentives as key driver** in supporting companies to adopt emerging technology • Companies are aware of two government incentives: o grants to purchase technology and; o grants for training and upskilling of workers in tech adoption. • Limitations include **grants limited to specific projects** and sometimes **only working with local partners** • Government is aware of the need for upskilling, with some organisations being built.

The definition of IR 4.0 technology used here follows how new technologies are able to exploit data resources. Four cross-cutting base technologies – data collection and network connectivity, cloud computing, big data analytics and Artificial intelligence (AI) - can be platformed at different levels from the production process to end-user experience. When technologies are implemented in stages and in modules, they will not cause major disruption in production. Instead, this process can lead to higher customization, which will benefit from the existence of an open innovation ecosystem.

Data collection has always been recognised as an important part of productivity improvement especially in management and production management (Sturgeon 2005). The availability of IR 4.0 technologies, especially with the availability of low-cost sensor technologies and radio-frequency identification (RFID) technologies are the latest evolution of productivity improvements. The data collected is accumulated over time, and together with increasing interlinkages between sensors and data analysis through the Internet of Things (IoT), allow for dashboarding where a single screen provides access to various pieces of information crucial to the production process. These data allow manufacturing firms to have a big picture view of the activities of the manufacturing process. Analysis of this data also allows for troubleshooting of the manufacturing process for improvement.

Further, computers have evolved from “dumb” individual computer terminals to distributed computing and storage, reducing connection latency issues. This allows for more reliable and secure data access for cloud-based remote analysis as well as data storage. The ability to store data remotely allows for decentralized data storage in large amounts beyond the geographical borders they are confined to, thus saving physical space, and keeping the data safe.

Cloud computing which serves as the storage system for data collected from sensors, and analytics on this data, can lead to deeper understanding of the data and can automate prediction and decision. These technologies are known as big data analysis and Artificial Intelligence (AI). These technologies drive the possibilities for better data-driven decision making by different stakeholders, especially with the availability of powerful processing chips. With these, organizations are able to use crowd-sourced insights and high-frequency sensor readings in predicting and modelling outcomes from various decisions. However, much of the AI technology currently remains in the realm of “specialized AI” where the system is only able to solve a limited number of specific problems.

These cross-cutting base technologies serve as the basis for further specialization in terms of the technologies in which they are used. For example, the use of an automated robotic arm would require sensors to produce data of the force and accuracy required in performing a task. This is done through transmitting data to the digital cloud and operated virtually through a remote control, in addition to offering recommendations, options, and solutions through machine learning systems. Here, we take the idea of cross-cutting technologies to help define how these technologies are used and specialized in manufacturing firms in Malaysia.

Technology Adoption and the Workforce

Labour-replacing or labour-augmenting: Effects of technology on workers

Technological change has brought much changes to the workers in terms of the type of occupation and task they do. An estimated 60% of employment in 2018 was found in job titles that did not exist in 1940 in the US, and similarly some jobs no longer exist today (D. H. Autor, Mindell, and Reynolds 2020). The speed in which these changes are occurring have accelerated, especially due to the computerisation and other automation technologies that have allowed for direct replacement of human labour or part of the task they can do are driving task-polarization (D. Autor 2022). For higher educated workers, these technologies augment the skills that they have and the tasks that they do. For middle skill workers such as production operators who perform routine tasks, they could be replaced by automation. Most workers such as care workers who perform manual but non-cognitive tasks are still not replaced by technology (D. H. Autor, Katz, and Kearney 2006; Frey and Osborne 2017; Goos, Manning, and Salomons 2009). This exacerbates inequality within the society due to skill-biased technological change, where middle skill workers, including operators and technicians in the manufacturing sector are adversely affected in income and jobs, while higher wage, higher educated workers benefit most from the productivity gains from the technologies (Acemoglu and Restrepo 2019). Separately, more occupations which perform non-routine, manual tasks but of lower waged are available - which may be the most viable option of the displaced middle skill workers to work in.

Given the trade-off between IR4.0 technology adoption and the rise of inequality, it is short-sighted to adopt IR4.0 only in labour-replacing technology. On one hand, IR4.0 technology will only displace certain tasks which workers do - workers have skills, techniques and experience that are needed to augment the technology adoption, especially non-routine cognitive tasks. Thus, successful adoption of technology in the long-run requires the experience of the existing workforce on the manufacturing processes, labour-replacing technologies cannot replace the knowledge of workers on the typically specialised and optimised processes of the manufacturing factory.

Labour-replacing technologies may also increase inequality, with the benefits accrued towards capital owners - labour-augmenting technologies have the potential to allow the productivity that comes with technology adoption to be more equally shared. Taking high-road business strategies and labour-augmenting technology adoption that co-create with workers and worker unions may not always be less efficient than purely adopting labour-replacing technologies (Kochan and Dyer 2020). Other than the issue of inequality, the multiplier effect from research and development into these technologies is greater than just technology adoption.

Changes in task content

Our interview has found that similarly in Malaysia, technology has tweaked the task content of jobs in the manufacturing firm, and thus the adoption of new technology requires workers to learn new technology skills. An example of this is illustrated by a food product manufacturer interviewed who described how traditionally, a chef's job description would be working with their hands and being in direct contact with ingredients to make food. With the adoption of technology, chefs are able to operate through IoT to control the production process and do not have to physically be in contact with ingredients or cooking utensils to produce food. The job description of a chef in a food manufacturing factory evolves to monitor and analyse the cooking pattern and processes through their smart phones and intervene with corrective action if needed.

> *"These Industrial 4.0 technologies allow the system to analyse the cooking pattern. [In the event of] any exceptions, it will send real time access to our chef's mobile network to take immediate corrective action. So, from the screen here, you can see that we can access our system and the cooking profile through the internet, by tablet or by iPhone, it will always notify you. If something happens, the notification posted will go directly to the chef's handphone to notify him that something has happened inside the computer." - Food Product Manufacturer*

As a result, tasks and jobs which traditionally were seen as unrelated to the use of technology, are evolving to incorporate technology. This makes tasks easier and more productive with higher safety standards in place on one hand but also requires the worker to learn new skills to adapt to the technology adoption.

For most cases where technology is adopted, most workers are upskilled and trained as they would still need to operate the machines/systems. Workers may also be moved to other jobs within the production line if their job is replaced by machines. Only a few manufacturers report a reduction in the number of workers over time as automation increases, with a sustained or increased output. In the case of one company, it was a reduction of 50% of manpower. In these cases, the type of workers whose jobs are being replaced by automation are workers in the production line. Engineers are less affected by termination due to the need for their knowledge to optimise the adopted technology.

> *"3 years ago, if you ask me this question, my answer would have been there are 1,100 staff*

in our company. Today I only have 495 staff. We have a significant drop in manpower but our business revenue, profit, and cash flow remains at the same level because we introduced automation and cut down the headcount. We make the machines replace a lot of manpower." – Metal Product Manufacturer

However, for some manufacturing sub-sectors, it is not possible for the entire production process to be automated. This shows the need for some manual processing which requires human labour.

"They have actually [automated] to a level of almost 70-80%. I think they are quite close to almost completely [automating] in my understanding. What is left, about 20% cannot be automated and we still need humans. Because the scale [of production] is so big, this 20% is not a small headcount."- Rubber Product Manufacturer

Acceptance due to improvement in work

In fact, most interviewees reported that their workers welcome, or at the very least, accept IR4.0 technology adoption with the view that it improves the work quality, offers them a chance to upskill and focus on other aspects of work which require them to learn knowledge-related skills. There is a transition from tasks requiring physical labour to tasks that require more thinking and less physical input, giving way to a new generation of knowledge workers in the manufacturing industry. The added task of interpreting information received or feeding information to these technologies encourages problem solving skills by engineers and operators, which in itself appears to be a motivating factor to adopt technology. This can be seen in the following quote from an interview with a technology adopter:

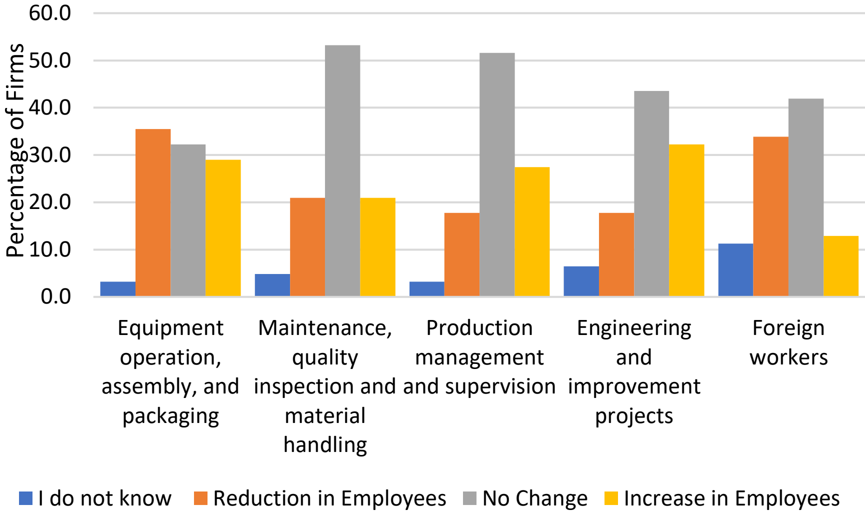
"After a while, the machine is able to learn by itself and no longer requires an operator. The operator will then look for other things to do. The operators will need to upskill. They will become an AI trainer, and do things like feed the AI with correct information. They no longer do repetitive tasks as the repetitive tasks will be done by the machine." - Technology adopter

For most firms, technology adoption has also been shown to improve the quality of work for employees in the manufacturing industry by optimizing working hours, reducing human error, reducing on-the-job and work-related stress, reducing manual labour, saving cost, and optimizing production time with real-time analytics. Improved working conditions for employees allow them to focus on analytical tasks, planning, and other tasks that improve the workflow instead of focussing on repetitive tasks.

"We have gone through the manual state, which is more labour intensive and we paid a lot for human labour. With new technology, the machines are fully automatic. We make fewer mistakes and [are equipped with] information such as downtime and things like that, so we are able to manage it more properly. This is easier for the manager, the engineers as well. The only important thing is that the maintenance must be very good." - Technology Adopter

Technology adoption has been shown to improve on-the-job safety for workers. An instance of this would be ensuring safety during product-testing. A vehicle manufacturer interviewed gave an example of this where in the past, a vehicle customisation manufacturer required workers to manually test product prototypes by riding them, which is a risk to the safety of the worker. With the adoption of IR4.0, workers no longer have to ride the prototype. Instead, a machine conducts tests of the vehicle's speed.

Figure 8: Changes in number of employees between 2017 to 2020



From the quantitative data, we found that most of our respondents reported no change in the number of employees, other than in the equipment, operation, assembly and packaging department where around 35% of respondents reported a reduction in employees (Figure 7). However, when asked about the reason for any changes in the number of employees in the equipment, operation, assembly, and packaging department, 30% reported that it is due to changes in demand for their products and only around 10% due to automation or digitization. Around 21% report that the changes in the engineering and improvement projects department are due to automation and digitization. Indeed, when overcoming the lack of skills, the mean reaction of our respondents is to rarely use the strategy of replacing workers.

Thus, from our interviews, firms have reported to have seen positive impact to the workers in terms of productivity and safety, with reportedly widespread acceptance of the adoption of new technology. The technology adopted seem to not be labour-replacing technologies, instead emphasising on the importance of training and upskilling the current workforce. This seems to indicate that Malaysian firms take a more labour-augmenting approach in technology adoption, with emphasis on training and reassignments, and provides an opportunity to further strengthen this approach for a more inclusive path to technology adoption. Our preliminary quantitative data also reports that majority of our respondents do not experience changes in employees.

Talent and skills - gaps and opportunities

Training and talent gap is the major barrier

Technology adoption requires talent who are able to not just utilize the technology adopted correctly, but also to optimize the manufacturing process. Training remains integral to continually improve the workforce to evolve in tandem with the technology adopted. The manufacturing industry is aware that talent is key to progress, and that solely adopting technology is not enough. This awareness is evidenced by the cultivating and nurturing of local talent and encouraging in-house tech development and employee-led tech adoption at company level.

Further, some local companies also cite the challenge of competing with companies from higher-income countries which provide higher wages. The younger generation may not find the salary and career trajectory offered by local companies attractive enough to stay. In particular, Pulau Pinang manufacturers lament the need for the younger generation of talent, and are quoted to say that the good workers migrate overseas, especially to Singapore, as the starting pay offered is higher. Some owners are quoted saying that the talent remaining are those that are not as high-performing academically compared to those who have migrated.

Many companies report a lack of talent and skills to be a major barrier to IR 4.0 deployment - companies need the appropriate talent to operate new machines and to effectively analyze data collected by the machines. However, the lack of local talent for hire hinders companies from progressing in their IR 4.0 journey. Small and medium sized companies are disproportionately affected by the lack of available talent. Multinational companies (MNCs) have a competitive advantage over the best talents available due to their stronger financial capacity to remunerate the best talent. According to the provider below, there is also a gap in employees' awareness of emerging technology and how it can benefit companies of all sizes, also due to headquarters support available to MNCs.

> *"In Malaysia, in general, the best talents are absorbed by MNCs. Those who are talented are top notch, the best ones. These are the people who understand technology well, know the value of technology, and who are exposed to the latest developments from advanced nations. I remember a few years back while promoting I4, we started in Penang, and we saw a huge gap among MNCs, LLCs [large local companies], and SMEs even on the part of understanding technology." - Technology Provider*

The lack of talents familiar with IR 4.0 technology were reported to have consequences. Mishandling or damage of these machines by workers incurs loss to the company, showing the limits of skills and talent present in local companies. This leads to underutilisation or inability to fully utilise the technology to its full potential, as described by a technology adopter.

> *"Interviewer: And even Malaysians you cannot trust them to change the setup of the machine?*
> *Tech Adopter: Only limited set ups. We tried this before, and after that we learned a hard lesson. A few machines crashed, and those were a total loss. Cost us a million. It's okay. But from there we learned we had to take it one step at a time." – Metal Product Manufacturer*

In this particular case, the company had invested in an advanced machine that would allow them to fulfil high-mix, low volume orders. However, because of the inability of existing workers to reconfigure it at each new batch, the management decided to not take such orders.

Skills training as the main solution

Skills training in utilizing new tools becomes a crucial avenue to address the lack of talent, which most manufacturing firms do at varying extents. More firms are involved in providing training on digital tools compared to training workers' expertise in tasks. Partly, this is a function of new technologies being developed to be easier from the user experience end, thus the training required seem to be a simple training of pushing buttons and easy monitoring of the process. The basic level of usage does not require complex understanding, where some technology providers mention that complex understanding might be too difficult for the employees. Engineers, technicians and operators are all involved in training, with engineers perhaps needing to have knowledge in more technical areas in information technology.

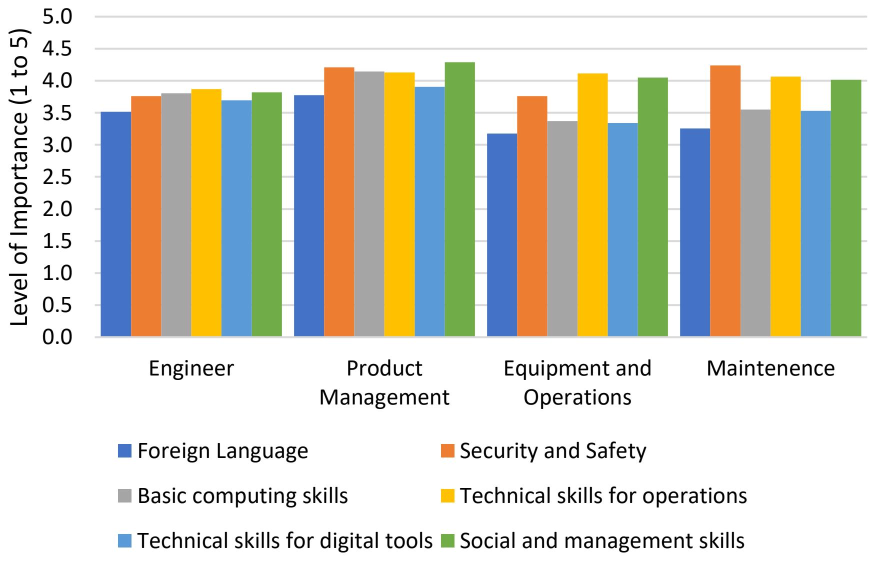
> *"Interviewer: Can the workers really have that kind of big picture understanding about*

> *OEE [Overall Equipment Effectiveness] and how the whole system works? Is that very challenging for them on a conceptual level? Are there other kinds of hard skills that they need to learn in terms of math and programming or anything like that?*
> *Tech Provider: So far we try not to get too complicated. We keep the mathematics and what not [out of it]. We do share, but it's not something they have to understand [in order] for them to operate the system." – Technology Provider*

However, a few firms were found to train their workers to have a technology adoption mindset and creating a culture and mindset of a digital first company. This includes creating in-house programs to encourage workers to appreciate the need for data collection and analysis as the basis for adopting IR 4.0 technologies, and enabling co-development of the technology to improve the specific processes' productivity or products. These companies also use this opportunity to create an internal team and community that can improve their own skills for the future and train a wider group of workers, as mentioned by a technology adopter:

> *"[There is] an advantage for them to improve themselves. [The] company will contribute in terms of the promotion of improving themselves through a skill or certified skill. [We cannot rely] only [on] the intelligence of the machine, but [we need to] also develop the person, the workers, toward IR4.0. In terms of improvement, certain processes which we currently use are manual. We implement automation and robotics to totally eliminate monotonous manual work which contributes to the ease of work and quality of products."*
> *- Technology Adopter*

Figure 9: Mean importance of skills by department



Using our preliminary quantitative survey, we found that technical skills for operations and basic computing skills are more important than technical skills for digital tools (including data analysis and programming skills) across all the departments - which is aligned with the findings from our qualitative interviews on the emphasis of training (Figure 8). To overcome the lack of skills, the most frequently used method is to simplify the work, followed by hiring workers with the right skills.

The capability and capacity for employee training and learning may also depend on the format of training provided to them. Some firms use the basic training services bundle provided by technology providers, and continue to outsource any technical issues to these technology companies, which may limit the skills transfer and development of the workers. Others have workers actively involved in skills training, choosing a "train-the-trainer" model to create key technology departments in the firm to train others, while others develop their own program and system. As mentioned by a technology adopter, the development of their own program allows for the knowledge to be maintained in the firm:

> *"In general, we have divided the project as such: we have an owner for every portion of what needs to be implemented, and they get trained. Recently, we have really been stepping up in the domain of knowledge transfer internally. In fact today I had a meeting with the whole factory team to discuss with them and asked that they record videos of it, otherwise they are for sure going to lose that knowledge. What I can see is that they say, let me train the guys in the factory first. I know that knowledge capture is never going to happen. So we're really focusing now on maintaining the knowledge, so we can really spread the knowledge." - Technology Adopter*

Manufacturers building their own training solutions

While the majority of manufacturers in Pulau Pinang mention the lack of local talent and lament brain drain, they do not seem to be waiting for changes to take place passively. Manufacturers themselves are putting mechanisms and programs in place to prepare the next generation of workers for the manufacturing industry. One such effort is a college set up by a manufacturer where students learn theory one part of the day and are given the opportunity for hands-on learning on the shop floor at the other part of the day. Some who have adopted IR4.0 have in-house talent to research and develop technology required and have gone on to become spin-offs, providing tech to other industrial players. Retaining and developing the knowledge and expertise will secure the future development of the firm in the long run as technological change pick up pace. However, since the majority of firms do not implement this training, this limits their skilled workers as technologies evolve, risking not only the workers but the firms, being left behind eventually. Outsourcing training may also limit the growth of the company by limiting its diversify to the high-value added part of the GVC.

Labour-intensiveness & foreign workers

Malaysia's labour-intensiveness of the manufacturing sector is a legacy of the economic structure in developing the country through manufacturing. Since the 1980s, Malaysia has been attracting foreign investment as a result of relatively cheap labour in comparison to developed countries but better infrastructure compared to its neighbouring countries, Thailand and Indonesia (Rasiah 1995). This led to the creation of a category of non-citizen workers, known as foreign workers[5]. Some manufacturing companies prefer foreign workers because of low wages, good attendance records, few to no employee problems, and because foreign workers rarely take sick leave.

However, the structure of hiring foreign workers does not incentivise firms to upskill workers. Foreign workers are hired on a limited fixed term of employment, forcing employers to constantly replace their foreign workers. This is considered a challenge as the newly hired employees will need to be trained and time is needed to familiarize themselves with tasks - the temporariness of new foreign workers deters investments into skills.

Nonetheless, employing foreign workers and investing into IR4.0 does not always seem to be

[5] Foreign workers are defined by the Immigration Department of Malaysia as workers who hold temporary visitor passes for work, and are typically not eligible for knowledge worker employment passes due to the low wages, and thus generally employed in low-skill positions (Immigration Department)

mutually exclusive. One example is a high IR4.0 technology adopter which tapped into the knowledge of their foreign workers who may also have bachelor's degrees and have work experiences on the machines used. Others also hire foreign skilled workers to suit the needs of the industry, as illustrated by a food manufacturer:

> *"Our foreign workers are not the people who only do the job repeatedly. When we introduced them to the technology and taught them how to implement and then [monitor their] performance, I found that some of my foreign workers actually have an undergraduate degree, a bachelor's degree [from] their country. So they are also happy that we can come [up with] some technology to assist them and then they understand how to use it then they also appreciate us [for it]." - Food product manufacturer*

However, the potentially rising cost of employing foreign workers may also encourage manufacturers to adopt IR4.0 technology. The Malaysian government has enacted a set regulation in place to ensure foreign labour recruitment does not encroach on job opportunities for locals. Although some technology providers (and a few adopters) are of the opinion that low-wage labour is still available in Malaysia, they believe that automating processes and adopting IR4.0 is important as the window for low-wage labour is quickly closing with the country's structural changes. In addition, the rise of human rights activism, awareness on sustainability and changes in government policies in the region are also cited. Therefore, Malaysia may not be able to compete with other low-wage destinations, which reinforces the need to upgrade its industrial activities. The following quote by a manufacturer illustrates this point:

> *"The overall trend is to go for automation because the window of opportunity is closing as Indonesia is coming up. It will be harder to get foreign workers due to human rights issues and sustainability issues. If technology and automation is not adopted fast enough, we are going to lose out to our neighbouring countries." - Manufacturer*

Government policies have indicated and signalled an increasing difficulty in contracting foreign workers in the near future. Some companies have the desire to adopt technologies that could specifically reduce their dependence on foreign workers. Given the availability of government incentives to train local workers, technology that could reduce the scale of foreign workers employed was found to be a motivating factor for technology adoption, as is quoted from an interview with a technology solutions provider:

> *"More companies are looking for alternative solutions to reduce reliance on foreign workers. They acknowledge that technology adoption has the ability to reduce their dependence on foreign workers. With the assistance that the government is giving during the COVID-19 pandemic, they are able to retain local workers." - Technology Solutions Provider*

The current recruitment of foreign workers is highly industry-specific. It is found that foreign workers are heavily recruited in the glove industries, for example, where there are more manual processes which cannot easily adopt IR4.0 technology. Conversely, the challenge in recruiting locals is the inability to attract them in sectors like plantation, agriculture, and manufacturing. Malaysians are, understandably, reluctant to take up lower paying and physically extenuating jobs[6].

Foreign workers play a major role in the current structure of the Malaysian labour force and the

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[6] The Malaysian Employers Federation is quoted saying that it is much cheaper to hire locals than to legally hire foreign workers as the cost of recruiting legal foreign workers is up to RM15,000 to RM20,000 per worker (https://themalaysianreserve.com/2021/03/31/cheaper-labour-but-local-workers-not-easy-to-attract/)

manufacturing sector in general. While employing low-wage foreign workers and technology adoption do still simultaneously happen, the changing economic and social environment are driving firms to look for technology adoption to reduce dependence on foreign workers. However, there will still be labour-intensive sectors which are inherently difficult to adopt IR4.0 technology.

IR4.0 in Malaysian manufacturing: motivations, adoption, and challenges

Digital technology adoption strategies

It is observed that Malaysian manufacturers interviewed mentioned that IoT platforms and sensors are the most frequently adopted technology as a result of the desire for data and the growing awareness of the importance of data in improving the manufacturing processes. IoT sensors and platforms form the central node of data collection in various parts of the manufacturing process to provide fast responses and remote monitoring, facilitating the use of dashboarding. Some manufacturers see dashboarding as one of the easiest jump-off points for utilizing data to improve the manufacturing process. In particular, visualization in dashboarding present users the conditions of the manufacturing process. The location and placement of the sensors from information from the dashboard depends on the experience of the operators – for example, leveraging on the years of experience of senior operators who intimately understand the manufacturing processes.

Cloud services also serve as another base technology which is frequently adopted. The main adoption comes from serving as a database of data from different sensors. Earlier technology adoption is related to the need for paperless systems within the manufacturing processes, which then evolved to greater decentralization of remote data storage with cloud service. Cloud-based solutions were also implemented in different parts of the manufacturing process, including in enabling remote monitoring and customer/vendor databases. The increasing bandwidth in internet provision and the incoming investments into a national 5G infrastructure will also facilitate global remote collaboration. Work-from-home arrangements during the COVID19 pandemic have also opened up a space for cloud-based solutions.

Compared to IoT and Cloud services, there are fewer mentions of big data analysis and AI adoption leading to predictive analysis. The deployment of these 4 cross-cutting technologies by the food manufacturer described below provides one of the best examples of adoption – the data collected is then stored in a cloud server accessible from anywhere, with AI/Big Data Analysis tailored towards better decision making by the operator. This includes optimizing older but customized manufacturing processes using a combination of these technologies.

> *"We install IoT devices [within the manufacturing process] to our old machines to capture big data for each cooker. This data from each cooker is stored in the cloud server, where machine learning/artificial intelligence is deployed* to *perform* pattern *recognition to inform decisions made in the cooking process. This is how we do it. IoT devices on our old machines send data to the cloud, cloud computing performs the analysis, and the end result of the analysis is fed back to us [for further decision-making]." - Food Manufacturer*

In terms of the combination of cross-cutting technologies, one of the main types of technologies are computer planning and Product Lifecycle Management (PLM). PLM manages data collected from various parts of the manufacturing process for the process to be easily observed and manipulated by users in different parts of the manufacturing management. The enterprise resource planning (ERP) system is one of the main PLM system that is used. Beyond that, these systems can also be used to perform controls and synchronization of different switches and valves.

The combination of the cross-cutting technologies can be used to drive robots and Automated Guided Vehicles (AGVs), using data that is collected mainly in a cloud system to drive the robots to perform certain actions within appropriate parameters. However, in some cases, the use of robots may not be necessary in the improvement of manufacturing processes and will not significantly impact every production.

> *"[Everyone in] the industry keeps talking about robotics, robotics, robotics. Every business owner I speak to, I say, look, we sell robots, self-collaborative robots. If you insist, I'll sell you robots but I'm just saying, you really don't need it." - Technology Provider*

Automated advanced inspection of products reduces repetitive work and manpower involved in the assessment of the product. Further, the accuracy which can be achieved by the automated advanced inspection is higher than the accuracy in inspections by human employees, thus augmenting the ability of human QCs to ensure product quality.

The quantitative survey results showed that cloud services, followed by IoT platforms and sensors were further in the process of technology adoption compared to big data and AI. The mean adoption level for cloud services was found to be between the pilot testing phase and the formal planning phase, while IoTs were found to be in the testing without implementation phase and the pilot testing phase. Big Data and AI technology adoption was still around the testing phase. The percentage of companies which have not considered or felt that cloud services and IoT platforms were not applicable are smaller than those for Big Data and AI technology adoption.

For the different technologies, more companies are at least at the initial studies in computer planning and PLM technology compared to all other IR4.0 technologies in the production lines - with the mean adoption between implementation without testing and pilot testing. However, for robots, AGV and automated advanced inspection of products, more than half of our respondents reported them as either not applicable or not yet considered, and the mean adoption being around at the initial studies stage and before. Further, more companies were also planning, considering and using flexible industrial lines and remote production monitoring and scheduling system compared to other more complex technology, such as additive manufacturing. Digital platforms that integrate customers and producers, such as CRM were also more likely to be considered and used compared to other customer-facing technologies. Interestingly, more than half of our respondents did not consider design-related technologies nor felt that design-related technologies were applicable to their companies, possibly indicating the position of the manufacturing firms being at the production-end of the value chain and not the research and development end for products.

Technology customisation and relationships with providers

New technology implemented in the manufacturing process usually requires unique customisation in order to optimize the unique production process, even if the factories are in the same sector. This was seen throughout small, medium and large enterprises interviewed in this study. Manufacturing processes in different factories, even within the same sector, were found to be sufficiently different from each other.

The need to customize technology in the manufacturing process resonates with the changes in product output due to available technology. In its current iteration, mass production enabled by lean manufacturing processes can be turned into mass customisation of products with new technology. The profit margin is reduced by simply replicating the same process and the same types of machines today. The ability to get the processes themselves to be mass customized through components unique to the sector and manufacturing process is crucial for the firm.

While most manufacturing firms of different sizes adopt a mix of strategies for customisation, technology customisation together with vendors is a shared key strategy for most companies. Much of this is driven by the inherently unique needs of each firm's manufacturing processes and this is reflected by most of the respondents. As discussed by a chemical sector technology adopter, most chemical companies need to customise in collaboration with both local and international technology providers, in this case machine makers as the processes and chemicals are different.

> *"Some of the machines, such as those on the plating line [are customized differently] because different companies run different processes and use different chemicals. So, each company needs to collaborate with machine makers [for customisation]." - Chemical sector respondent.*

This collaboration between the vendor (technology provider) and manufacturer (technology adopter) is even more important when the manufacturing process is a pioneer and does not have peers in the industry to emulate. In some cases, the manufacturing firm's own engineering team designs the system in close collaboration with the vendor to build the manufacturing system.

Some adopters customise in collaboration with vendors so that they control the direction of the technology used to have the flexibility to improve and customize the technology. This is in contrast to adopters who rely on vendor customisation or direct off-the-shelf purchase, where the product is sold as a complete package. The examples are seen across manufacturers of different sizes. Technology providers see this interaction in terms of a collaboration instead of the provision of a service and will benefit the technology providers, even though it is not seen directly so by the adopter.

The internet has allowed for technology providers to easily monitor customisations. This has enabled quicker service from vendors and the possibility of fully out-sourcing customisation and all the subsequent maintenance and further tweaking without the provider being based locally, as discussed by a plastics manufacturer:

> *"If you want to buy Chinese and Japanese equipment, there is no problem [in communicating with the vendors], especially for China. [We use] WeChat, it is very simple. You can send [the vendor] a message anytime and he will reply to you in less than 5 minutes. This is how it is. There is no issue with the service side of things." - Plastics manufacturing*

Finally, full internal customisation was mentioned by local large companies and MNCs, especially due to the ability to internally fund the technology adoption. One important reason for full internal customisation is the unique software required in the manufacturing process, which vendors are not able to deliver to fit the unique manufacturing processes required by the company. For some local companies, these internal teams are able to build their capability to the point where they are able to create a spin-off or specialized business unit, which offers solutions and technology customisation to manufacturers who require similarly unique technology. MNCs may also place their internal teams regionally or even internationally, thus the development is integrated across borders. In these cases, local teams will provide skeletal support, but are guided by their counterparts in the global system.

Data from the quantitative analysis showed that other than technologies coming from open sources or from other technology organisations, the majority of the companies have some level of customisation to their technology adopted. This suggests that the benefits of the expansion of IR 4.0 in Malaysia can go much beyond the factory floor and also provide opportunities to other firms in the service sector, such as technology integrators.

Global Value Chain and Technology Adoption in Malaysia - Global motivations

We observed that the Malaysian manufacturing sector's position in the GVC influences the decisions and speed at which the technologies are adopted. The evolution of IR 4.0 technological innovation is impacting GVCs, division of labour and business activities for small and large companies across the world (Muhammad Mohiuddin et al. 2022). Our findings show evidence on how the GVC is connected to firms' decisions on sourcing of technologies and how a company's level of GVC participation can determine their motivation to adopt technology. Indeed, technology adoption in the manufacturing sector, further accelerated due to Covid 19, has the potential to leverage on technology to build GVC resilience against future shocks (Spieske and Birkel 2021).

A large portion of global literature on drivers of industrial upgrading suggests that developing country suppliers' motivation to upgrade is determined by the buyer firms based in advanced economies (Ponte and Ewert 2009; Tokatli 2013; Yeung and Coe 2015). While this does not mean that all firms behave this way, it does indicate that most manufacturing firms in developing countries mostly do not occupy the lead position in the governance relationship in the GVC (Gereffi, Humphrey, and Sturgeon 2005). From this lens, questions such as whether multinational firms actually support upgrading or hinder companies in emerging economies in progressing towards high value-added operations can be examined. The Malaysian example could provide an important view to this question.

Integrated global MNCs dominate decisions in technology adoption

MNCs which are integrated globally were found to have the power to determine whether local branches are able to automatically choose which technology and from whom the technology is adopted. It is however unclear what factors determine what level of autonomy is given to local companies to choose their supplier. What is certain is that some integrated global MNCs make decisions on technology adoption centrally from headquarters, or that the decision is made by the global team wherever they are located. In specific industries, such as the automotive industry that have high safety protocols, technology adopted is centrally designed or decided in MNC companies' headquarters and subsidiary companies in different parts of the world adopt accordingly.

Some lead firms require Malaysian manufacturers to meet existing standards which the lead firms require in a relational or modular governance, where the lead firms are in constant communication with the supplier on achieving the required standard. This illustrates how customer's country level standards and requirements play a part in shaping the technology sourcing decisions of firms in emerging economies through mutual agreements. This can also determine investments of local firms, as explained by a semiconductor manufacturer:

> *"They have very stringent requirements on their product, requiring for us to use parts from European suppliers, American suppliers, and Western suppliers, particularly material and consumables making the parts according to these requirements and*

> *specifications to qualify ourselves." - Semiconductor Manufacturer*

In reverse, the lead firm can also choose not to upgrade due to the regulatory requirements on their market, as was mentioned by another medical devices company due to the reluctance to conduct another round of Food and Drugs Administration (FDA) approval by the lead firm.

In contrast to the above, an established electrical and electronics local large company, in the excerpt below, has a more captive value chain participation, with a small number of international customers that shapes the kind of processes and production line of the manufacturer. However, the IR 4.0 technology adoption and evolution of processes is driven internally by the local company and sourcing of equipment is not dictated by customers in developed economies.

> *"We started evolving our process internally ourselves, together with intervention from customers as customers will verify and provide suggestions while we build the process. The product and product design may belong to the customers, but the whole process and majority of the equipment belong to us." - Technology services Provider*

However, most of the Malaysian manufacturing sector comprises mostly second or third tier suppliers, and are companies producing at high volume but for low complexity products, labour-intensive, and with seasonal demand, which does not give these companies much of an impetus to invest in expensive capital machinery. This observation suggests that whilst there is room for these types of firms to benefit from upgrading through technology and move up the value chain, the current status quo of their business model does not necessarily benefit from an ROI that is significant, thus hindering companies to automate.

Some companies' drive to adopt technology still do respond independently to the external pressures of market demands. In order to stay competitive in the market, technology was adopted to improve industrial performance. The ability to produce better quality products and reduce time to market are important, as discussed by a technology provider,

> *"Generally, this part of the region takes about 18-24 months to identify, decide how to, and fully develop a field. Our job is to help them through a digital transformation process by providing lots of visibility and connectivity between multiple domain applications and multi-discipline engineers that they can interact with. Our focus is on reducing from this 18-24 months to as fast as 12-15 months. This will naturally increase [manufacturers'] productivity, time to market, and also competitiveness." - Technology Provider*

Companies that are able to achieve a reduction in time to market by adopting technologies that increase their productivity allows them to adopt more competitive pricing. The data collected from IoT technologies allowed companies to conduct data analysis to improve the performance of their machines and, if taken further, explore new business models.

Industrial performance - motivations and challenges

Within the firm, the most widely observed driver of tech adoption among manufacturing companies in Malaysia is the desire to improve industrial performance. Improving "industrial performance" in this instance encompasses a range of outcomes including increasing efficiency and productivity, improving quality control, and increasing the scale of output and revenue. Firms adopt tech with the aim to achieve one or more of these outcomes depending on their specific needs. Another important driver is that the adoption seems to be incremental in nature, where it is done to tackle the issues in production efficiency the firms face from day-to-day.

Improving efficiency and productivity of production processes was seen as a key driver to adopting tech for some companies. This includes reducing cycle time and increasing the volume and scale of production. Indeed, companies that work with multinational companies find that improvements in efficiency and productivity strengthen their relationships with these MNCs. Improving efficiency in their processes have further allowed companies to reduce consumption of energy. Technology providers in energy modulation and measurements, with increasing sophistication such as AI energy modulation, further improve the efficiency.

Other companies were motivated by the benefits of improved quality control for their products. The data collected from technologies implemented in quality control processes allows workers to trace defects and resolve issues faster and more efficiently, and allows prevention and reduction of mistakes.

Beyond that, the ability to minimize capex whilst improving productivity and increasing revenue is another key motivation to adopt IR 4.0 technology. However, small and medium sized manufacturers would need to have the initial capital to include this in the budget for their capex.

The ability to reduce the scale of the workforce whilst maintaining revenue and productivity is another driver of technology adoption, in some cases translating to improved efficiency. However, the companies that seem to do so are second or third tier, labour intensive manufacturers, such as the metal manufacturer below:

> *“We have a significant drop in manpower but our business revenue, profit, cash flow and output remains at about the same level because we introduced a lot of automation and cut down a lot of headcount.” - Metal manufacturer*

Technologies that can increase the flexibility of one’s workforce and reduce the physical space needed to run operations were also an appealing reason to adopt IR 4.0. The growing culture of increased productivity through shorter timelines and shorter lead time in the market seemed to pressure companies to adopt technology. This includes implementing technologies that increased the flexibility of remote working, resulting in cost savings from reduced travel time when controlling operations in different locations.

There are few obstacles still exist in a firm’s pursuit for increased industrial performance. One manufacturer cited lack of understanding, and uncertainty as to whether IR4.0 adoption would benefit the company and industry. Another automotive company also cites the inherent low demand for the product does not necessitate IR4.0 technology adoption:

> *“In Malaysia, our annual sales are around few thousand units. I think last year was another record-breaking year, our highest ever. In the big scheme of things, few thousand cars [is a small number] if you [compare it to] our global sales [which is] around close to hundreds of thousands. So, in terms of our power, saying power is not there, because Malaysia's economy also not very big and terms of how we can then, first wait or how we can then try to convince our HQ regional colleagues the power is not great.” - Automotive manufacturer*

A few companies have manufacturing processes that are not traditionally automated, and in fact technology adoption obstructs the production flow as illustrated by this company:

> *“Even though the boss, the General Manager, says to use our new machine [since] we paid so much for it, the production managers and operators don't want to use it because our products are so small. We put [them] on the tray and all these products scatter. [Since] it's*

> *scattered, not on the tray, the workers have to manually rearrange [them] which means [it becomes] a double job … Now the machine is burdening them … so, we return to the old process." - Tech adopter company*

There were mentions by small and medium sized companies of struggling with the shortage of appropriate manpower to maximize the benefits of the data generated from the machines. Whilst some local medium and smaller companies are motivated to adopt, the speed at which this occurs is slower compared to local large companies and MNCs - which is also observed in the US (D. H. Autor, Mindell, and Reynolds 2020).

New IR4.0 technology adoption at the firm level may possibly serve as a pathway for the Malaysian economy to grow beyond the production part of the value chain which is at the risk of no longer being the driver of value and growth. Only few technology adopters and providers have mentioned the development of new products or new innovations their customers are able to obtain, and most are at the beginning stage. Many of these adoptions are still at the stage of improving productivity allowing for new business opportunities instead of new products or services outright. This can be true for MNCs and local companies. This raises questions on whether continued investments into the production phase which is decreasing in value add along the GVC and not diversifying higher-value add activities might adversely affect the growth of the firms and manufacturing sector.

Government incentives - building capacity

A key driver that has supported companies to embark on adopting emerging technology is the availability of government incentives. Government incentives in the areas of IR 4.0 in the manufacturing sector in Malaysia appear in two forms:

i. Through grants that support companies to purchase technology and
ii. Grants that support training and upskilling of workers to ensure tech adoption.

Appendix 1 outlines the different government incentives available for IR 4.0. Many companies highlighted how available government incentives allow them to work with the government on specific needs and design a way forward to adopt new technologies into their existing processes.

> *"Industry 4WRD intervention. Yes, we have actually engaged with these government agencies through SIRIM. There have been people from you know, SIRIM team coming over to factories, spending two days, walking around, auditing, understanding what our needs are. You know, towards 4.0 and then providing us information, and you know again working with us on building up the roadmap." – Textile Manufacturer*

Training grants are provided by the government through the Ministry of Human Resources via human resources development agencies and funds. These trainings help raise awareness of IR 4.0 in general. Government policies or incentives are available for companies as well as upskilling of workers to adapt to the changing processes in companies.

> *"So, they give us training so we understand what is IR4.0 and what the government's policy is right now so that we can move towards that industry. But in terms of training, after that the government has provided us, we too had our internal and external [training]. The government has a HRDF - HR Development Fund[7] - which is a fund for us to have external training on IR4.0. We are also going to have our internal training so that there is knowledge sharing with our staff and workers on this." - Food Manufacturer*

Whilst many companies cite the benefits of these government incentives in facilitating the transition to IR 4.0 technology adoption, some companies have highlighted the limitations of the current system. Companies are limited in using it for supporting specific projects and are sometimes required to only work with local partners, as mentioned by a local manufacturer in the interview:

> *"We are familiar with grants that the government is offering. We are one of the benefactors of the government grant. The only limitation is that the government grant is not very flexible. Sometimes they limit the usage [of the machine] based on the project. If you have project A, and if you buy a machine for project A, they will say, okay, this machine can only be used for project A and you are not supposed to use it for something else. There is always a limitation. They want us to work with local agencies e.g. SIRIM, or a local university, or local hospitals." - Local Manufacturer*

Beyond grants, the governments and private sector players are aware of the various issues related to talent and upskilling. Thus, the government collaborate with various training institutions to address the shortage in talent. For example, companies in Penang have found the Penang Skill Development Centre (PSDC) to be beneficial in supporting recruitment of engineers, while the Selangor Human Resource Development Centre (SHRDC) trains workers based in Selangor and beyond.

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[7] HRDF has been renamed to the Human Resource Development Corporation (HRDC) in 2021.

PART V: Discussion and Policy takeaways

As new technologies and processes are being adopted by the manufacturing industry globally, and Malaysia's manufacturing industry being export-oriented, there is a need to adopt IR4.0 in order to maintain Malaysia's market responsiveness. While the nature of technology adoption in Malaysia still remains at IoT and cloud adoption, external GVC pressures, industrial performance demand, changing natures of talents and jobs and government programs and incentives are impacting the nature of technology adoption and jobs. Thus, a key to thinking about technology adoption is to consider beyond the technology itself, but the whole process and behaviour in the use of technology (Ellul 1964).

Talent and skills are the most important factor cited by the respondents – investing in new machines and solutions are not sufficient when the lack of talent may end up with more damaged machines than productive ones. Adoption of IR4.0 requires upskilling of both skilled and semi-skilled workers. Some employers have reported that there are instances where expensive machinery has been damaged due to mishandling by workers, which calls for upskilling and training to bridge the skill gap. The acceptance of current levels of technology adoption, accompanied by upskilling and training have been reported by employers to be positive across the board, with few instances of resistance. Only one instance found engineers showing greater resistance. Some high-adopters work with employees to further the conceptual understanding of using IR4 technology beyond just providing technical upskilling. Another issue mentioned by manufacturers across the board is the lack of local talent available to handle and optimise IR4.0 adoption. One of the reasons mentioned by local companies is how MNCs have absorbed most of the local talent, while others mention the migration of talent to neighbouring countries which can provide higher incomes.

However, there have been government and state efforts to strengthen and increase the technical and vocational workforce for the local manufacturing. Some manufacturers too have set up colleges where school leavers are able to attain the skills required for the manufacturing industry through theoretical study as well as hands-on work. With resources for training and skill-learning in place, it is important for manufacturers to attract these talents as well as offer fresh graduates from engineering programs the opportunity to be trained on the job.

The perceived threat of IR4.0 adoption drastically reducing job opportunities and eliminating the need for human workers is not found to be true for the case of Malaysian manufacturers interviewed for this research. The impact of IR4.0 on the current manufacturing system is a restructuring of job levels and job descriptions. Both semi-skilled and skilled workers would most likely need training to adapt to adopted technologies to evolve with the evolution of job descriptions which goes hand-in-hand with IR4.0 adoption. Local talent would need to grow in knowledge and ability in order to optimise IR4.0 adoption. This could also be an opportunity - some of these in-house technology adoption departments have become spin-off solution providers for other companies in the industry.

A key feature of technology adoption in Malaysia is its relationship with the GVCs. While technology adoption is customised to the industries and products of the manufacturing firm, the drivers and barriers of technology are dependent on the *type of firm* in relation to the GVC. The different mode of governance in terms of the GVC shapes the relationships which determines how the technology is adopted. Multinational companies with integrated productions respond to the needs of the international production system, and technology adoption decisions lie with the headquarters. Local companies which serve as suppliers have to comply with the requirements of the lead firm, including the technology used.

Technology adoption to improve industrial performance is an important driver, albeit in an incremental fashion - both for companies tied to global MNCs or not explicitly. The opportunity to improve industrial and worker performance is important to the firms, especially so when some labour-intensive manufacturing sector utilises large numbers of low-wage, manual foreign labour. This is due to the increasing difficulty in hiring foreign workers due to regulation. The adoption of IR4.0 has reduced the need for labour intensive, repetitive work, which in turn, shifts the job description of lower-skilled workers to less labour intensive, less repetitive to requiring a minimum level of skill requirement. This may introduce competitiveness amongst manufacturing companies and incentivises the companies to improve treatment of lower-skilled workers in areas of wellbeing and training provided. The impact of IR4.0 adoption on foreign workers has exceptions in certain sub-sectors. In the rubber glove manufacturing sub-sector, parts of the manufacturing process still require manual labour, which are commonly provided by guest workers. However, these instances are very rare.

Whether the adoption of IR4.0 by Malaysian manufacturers will result in structural progress that is incremental or whether it progresses rapidly is yet to be seen. In both cases, training and development of talent is crucial in optimizing IR4.0 in the growth of the manufacturing industry in years to come.

Policy pathways

Government policies have played an important role in the signalling and raising the need and awareness on technology adoption, however there are crucial limitations. These policies are usually not the main driver for technology adoption, and the incentives and programs are limited by the local content required, the lack of business planning skills by traditional firms or the lack of technical skills to fulfil the perceived high requirements in the foundation manufacturing processes required before the manufacturing firm is eligible for the incentives. These may explain the slow uptake of the IR4.0-related incentives (Amarthalingam 2017).

To tackle these issues, policy pathways beyond this will require thinking over matching the structure and relationships of our industries with the GVCs and the gap in talent and skills, while acknowledging the need to increase productivity and moving away from labour-intensive manufacturing. Current policies point towards a gap in matching the actual technology requirements of the companies especially with an incremental nature of adoption, while fewer discussion over how to address the question of talent and skills. Technology adoption has yet arrived at the pace where labour has been replaced - which may be a sign of the labour-intensiveness of the industry, but more crucially from our analysis that firms are considering technology adoption but have yet to adopt. In other words, there is increasing awareness, but also a wait-and-see approach. This provides time and space for policy to address these questions before the issue of unemployment from automation is added into the pile.

A synergistic governance supporting the transition into IR4.0 is crucial in ensuring that firms, while upgrading in global supply chains, maintaining responsibilities in managing the impact and risk of IR4.0 adoption on workers. Potential issues in IR4.0 adoption on workers are how varied types of economic upgrading could affect labour conditions, including low pay and undesirable working conditions, and the effect on particular groups that are more vulnerable than others such as women found to be frequently left out in social upgrading (Carr and Chen 2004). IR4.0 can also be seen as a tool for social upgrading. As firms adopt more technology, it is important to move to higher value paths of production in order for social upgrading. The six potential trajectories of social upgrading in industrial clusters and GVCs outlined by Gereffi and Lee (2014) suggest pathways that can be steered by different levels - public, social and private governance.

i. The *market-driven path* is driven by the demand from the market for goods produced in good working conditions and by firms who prioritize worker welfare.
ii. The *CSR-driven path* is driven by global buyers' demand for clusters to comply with codes of conduct. This enables global buyers to avoid reputational damage in cases where labour wrongdoings in supply chains are exposed. Limitations to this trajectory include the demand of buyers for low cost while at the same time having expectations for labour code compliance.
iii. The *multi-stakeholder path*'s foundation is cooperation amongst stakeholders such as governments, clusters, global lead brands, international and local NGOs, trade unions, industry association and firms in a shared initiative to promote improvement of working conditions. This trajectory combines compliance-monitoring with capacity-building, thus enabling clusters to address labour issues independently (Locke 2013)
iv. The *labour-centered path* is led by workers' unions and associations, centered on workers' rights.
v. The *cluster-driven path* is led by cluster firms (business associations, chambers of commerce, cooperatives, etc.) to implement and monitor labour codes and improved working conditions while taking into account local considerations and local contexts in a trusted way within the tight-knit cluster community.
vi. The *Public Governance path* government-led regulations and policy, or a public governance driven path in upgrading clusters and GVCs (Gereffi and Lee 2016), is an effective way to make the farthest-reaching impact by including all suppliers within their jurisdiction, whether within or without a GVC or Cluster (Meyer and Gereffi 2017). Instead of merely functioning to "enforce laws", government ministries, the courts, and local and national level inspectors can act in more "innovative and experimental" ways by working together with other stakeholders to provide firms with incentives, technical assistance, encourage capability-building initiatives, and other types of support (Locke 2013). In Malaysia, various country-level regulatory efforts have been made such as the ratification of the Protocol of 2014 to the Forced Labour Convention, 1930 (No. 29) to fight against forced labour.

Any one stakeholder alone cannot shoulder the responsibility of upgrading, while responsibly managing the impact and risk of IR4.0 adoption on workers. A synergy of governance and cooperation amongst firms and stakeholders could provide a pathway to IR4.0 adoption in which workers, which are the most important element to IR4.0 adoption in the manufacturing industry, are impacted in positive ways.

Short-term Policy Pathway - Building Pathways to Talent & Training

As with the past, technological changes such as IR4.0 adoption will eliminate some jobs, while creating new jobs (D. H. Autor 2019). McKinsey Global Research Institute found that approximately 30% of tasks affecting 60% of current jobs will either be eliminated or undergo significant change in the next ten years (Chu, Manvika, and Miremadi 2016). Expert views are tied as to whether IR4.0 adoption will serve to significantly create more jobs or conversely, eliminate more jobs than it creates. Kochan (2019) cautions that viewing the effects of IR4.0 adoption on the workforce in dichotomous terms is futile and instead recommends approaching the effects of IR4.0 by looking at work as a collection of combined tasks and how each of these tasks undergo change with the adoption of technology, and subsequently, addressing how workers respond to this change.

Malaysian manufacturers reported adopting IR4.0 either incrementally or adopting technology specific to certain tasks within their respective manufacturing processes. Some processes were not able to be automated fully and required human labour for certain tasks within the production line. In both cases, the central question is how do organisations and workers respond to the change brought about by technology adoption. The response to this question across the board was companies lamenting the need for skilled workers and talent in order to operate adopted technology. Some manufacturers reported heavy loss borne as a result of the mishandling of new machinery. Unfortunately, the default reaction was to limit the customization of their new machinery to avoid problems instead of upskilling their workers to operate more advanced equipment in their full capacity. To date, although in-house upskill programs and training from solution providers are available, there is a need for a growing number of trained workers in Malaysian manufacturing companies.

Neighbouring countries to Malaysia such as Singapore face a similar challenge. Singapore was reported by CPA Australia as the Asian country with the highest likelihood of adopting technologies, especially robotic process automation (RPA), and of developing a long-term technology strategy. Coupled with the Investment Allowance Scheme made available until March 2023 by the Singapore government, the country is poised for a successful automation revolution. However, Singapore admittedly faces a lack of talent (CPA Australia 2021), especially in the areas of programming, cyber security, and data analytics, even though 'technology jobs' will continue being in high demand over the coming years.

Much can be learned from South Korea, a country where government-led skills development was put in place from the very start of its industrialisation to ensure a continuous supply of skilled workforce and as a measure to protect vulnerable groups. Government-led intervention was crucial to Korea's fast-paced industrialization in tandem with the mass migration of unskilled workforce from rural areas to urban areas (C. Lee and Chew-Ging 2006; C. Lee and Hutchinson 2017; Ra 2012; J.-W. Lee, Han, and Song 2019). However, the problem faced by Korea which caused the government-led intervention in worker upskilling was companies poaching workers who were trained by other companies rather than doing the work of training their workers, thus providing general training at the very minimum. This practice resulted in varied and unequal skill levels within the national workforce, which in turn caused wage disparities. The government had to turn from the free market upskilling approach to stepping in in order to provide training for equal employment opportunities and income distribution. The successful intervention of the Korean government in ensuring a steady flow of skilled workers suited to the evolution of industrialisation in Korea is attributed to the government selecting core industries to be developed (e.g. the light or heavy chemical industry) and not relying on employers to train workers as their existing training capacity was insufficient (Cheon 2014). To date, positive effects of Korea's vocational training programs are apparent on workers' wages and the probability of individuals being employed. Korean researchers suggest expanding these programs to Korea's rapidly aging population through lifelong learning programs and vocational training for the elderly (J.-W. Lee, Han, and Song 2019). The success of Korea's government-led skills and talent development program can be replicated by Malaysia in training local talent and workers.

Another important talent pathway comes from strengthening the technical and vocational education system – with successful examples such as in the dual-education apprenticeship in Germany (Ibsen and Thelen 2020; "The German Vocational Training System - BMBF" n.d.) To date, Malaysia has more than 500 Technical and Vocational Education and Training (TVET) institutions across the country (Ministry of Education, n.d). In addition to providing skills training, partnership with the private sector, namely, manufacturing companies through government-led programs would strengthen the incoming workforce's know-how and familiarity with IR4.0. Already, local manufacturers in Pulau Pinang offer STEM initiatives, maker spaces, training and development programs, and TVET programs at secondary school leavers level to provide real-world training experience. The mode of knowledge transfer no longer needs to be textbook and chalkboard style. In fact, many manufacturers interviewed shared a common complaint of fresh graduates not having the necessary skills and had to be trained on the job. Clearly, industry-driven, real-world skills are also essential and new platforms that do not necessarily emulate formal education are vital to the readiness of incoming talent. While manufacturers provide in-house training, government-led initiatives to equip talent with real-world, industry-driven, skills are essential in order to prepare the workforce to prevent skill-based technology change. This will reduce the potential inequality and wage gap within the workforce. Besides training workers and talent in hard skills, government and industry led initiatives need to equip the workforce with the capability to thrive in an ever-evolving, fast-progressing environment.

From a social contract perspective, incentives such as attractive salary and training policies would be useful in encouraging workers to upskill in tandem with the adoption of technology. Training policies can be put in place to motivate workers who upon signing on to a job, are presented with the possibility of an upwards career trajectory available to them regardless of their entry level. With the help of government incentives and funding programs, manufacturing companies would be encouraged to implement these policies. This is especially so for local companies when multinationals and neighbouring countries are able to offer higher and competitive wages.

Trained talent also was observed to company-hop within manufacturing outfits within the country, according to local manufacturers. This should not be seen as a negative trend. Instead, this can be the formation of the community of talent gaining experience in different manufacturing settings, which in turn fosters knowledge sharing and innovation. Some companies in the interviews were able to grow teams of talent who not only provided in-house tech solutions but evolved into spin-off solution provider companies, offering tech solutions to other companies in the manufacturing industry. Therefore, creating and training in-house talents provides an important pathway for firms and companies to diversify in the GVC to capture higher-value added activities, such as R&D and services. Conversely, outsourcing training, which most companies we interviewed do, may cause the company to lose it’s competitiveness in the GVC.

The drive to adopt technology in Malaysian manufacturing companies is not spearheaded solely by owners and upper management. Some high-tech adopting manufacturers interviewed reported that working with production employees is important in ensuring the success in adoption. The co-creation and establishing IR4.0 technology within manufacturing companies is crucial, not simply just the buying of latest technology nor the use of the most expensive machinery in the market to automate processes. Without workers and talent, the adoption of any tech will result in it being at best, a white elephant on the shop floor, and at worse, incur losses to the company.

Medium-term Policy Pathway – Matching Incentives to Needs

Technology adoption is something that employers are aware of, but it is mainly driven by internal productivity needs, or client or lead firm requirements. Technology investments do not seem to depend on policy incentive provision per se, instead it is driven internally by the lead firm or as a consequence of being part of a larger multinational company. The type of technology investment is also incremental and iterative in nature, and the choices of adoption depends on the requirements of the manufacturing process, especially when the technology required are usually highly customised to the manufacturing process.

However, the available incentives and funds by the government are reported to not match the requirements of the companies. Issues that were raised include restrictions to source the technology from a single source which must be a local supplier and integrator, when these technology suppliers may not have the skills to provide for the highly customised manufacturing process by themselves. The incentives were also aimed at the adoption of much more sophisticated IR4.0 technology which the current manufacturing process does not need, that the companies do not have the talents to operate them or that the returns of investment from the technology upgrade is not viable. Indeed, some companies have found that innovation or scientific funds were more useful in allowing iterative processes of building technologies that fit the needs of the firm and mixing and matching components from different suppliers at a lower cost.

Developing incentives that match the entrepreneurial discovery of new activities to diversify the economic structure brings in longer-term development, as will be discussed further. Developing these entrepreneurial activities may not require large subsidies, instead incentives which can assist the discovery and match the conditions to build that new activity is crucial. These incentives include skills training, technical support from training and technical centres, grants to allow for customisation and mix-and-matched machines customised to the manufacturing process would help firms innovate along the way. Some local companies or a coalition of companies, such as the Vitrox Academy, have already developed training centres and academies aimed at growing and training their collective talent pool. The state can support, develop and expand this existing space as the education, training and innovation platform for the pool of talent to benefit the whole manufacturing sector, including forward-looking innovation programs.

Long-term Policy Pathway - New Industrial Policy

Malaysia is a part of the remarkable success of the East Asian industrial policies that has led to the effective use of the manufacturing sector as the escalator of growth, leading to the remarkable improvements in household incomes and living conditions (Hausmann and Rodrik 2002). This can be seen by the higher development levels in Malaysia compared to Ghana although both declared independence in the same year from the British Empire. However, compared with other East Asian nations which adopted similar policies, countries such as Malaysia experienced premature deindustrialisation before achieving high-income nation status due to the changing nature of trade and globalisation, including the reduction of relative price of manufacturing in the advanced countries, putting pressure on manufacturers across the world (Rodrik 2015).

One observation may offer a way out - diversification of sectors and jobs within the economy, rather than conventional comparative advantage such as lower-waged workers drive economic development (Rodrik 2004). To achieve that, creating a space for entrepreneurs to "self discover" new activities and venture to Malaysia will be important, while also solving the coordination issues in establishing the logistics, supply chain, utilities and etc. Such activities can be best done by the state. This includes ways to build the ecosystem of entrepreneurs in new areas of growth, support specific activities instead of sectors, but most importantly knowing when to pull the plug when the activity fails. These policy choices may not need to involve large amounts of subsidy - if subsidies are poorly implemented, the state may end up subsidising large multinationals from developed country with little benefit to the state and the economy. Thus, the institutional architecture is important to establish the ecosystem - this includes political leadership that can drive the agenda, coordination and deliberation councils, mechanisms for transparency and others. The state can take a mission-oriented approach in promote this discovery, where grand challenges to solve some of these issues can be taken into consideration (Mazzucato 2021).

Malaysia, by and large, has had institutions set up since the 1980s to build ecosystems, from development banks such as the Malaysian Industrial Development Fund (MIDF) to provide capital investment, Malaysian Investment Development Authority (MIDA 2020) to oversee investment, SME Corp to support SMEs and others. These institutions are always key to our ecosystem. What remains is to reorient the agencies on the next mission problem to build.

Appendix 1: Government policies for IR4.0 technology adoption policies

To ensure Malaysia continues to grow the manufacturing sector via the adoption of IR 4.0 technology, the Malaysian government has invested in several financial incentives through different national policies, over the years. Policies in Malaysia, however, use a set of definitions popularized by the World Economic Forum setting IR4.0 technology as a set of 9 pillars of technology. However, these concepts continue to shift depending on the understanding (Yang and Gu 2021). IR 4.0 technologies in the context of Malaysian policy looks at technological drivers that leads to the digitalisation of production industries (MITI 2018). This includes the following:

- Big Data analytics
- Artificial intelligence
- Augmented reality
- Additive manufacturing
- Cybersecurity
- Simulation
- Advanced materials
- System integration
- Autonomous robots
- Internet of Thing (IOT)
- Cloud computing

In the 11th Malaysia plan (2016-2020), the government included a few strategies to boost the declining manufacturing sector such as upgrading products, improving productivity, stimulating innovation, strengthening growth enablers and increasing internationalization. More recently in 2018, they introduced the Industry 4WRD: The National Policy on IR 4.0, under the Ministry of International Trade and Industry.

The government had allocated RM 210 million to the industry 4WRD policy between 2019 to 2021 to support the manufacturing sector's transition to Industry 4.0, especially for small and medium enterprises. The main aims of the Industry 4WRD policy are to increase manufacturing productivity for every worker by 30% and increase the sector's contribution to the national economy from 254.7 billion to RM 392 billion. The government also aims to strengthen Malaysia's capacity and capability for innovation by improving its ranking in the Global Innovation Index from 35 into the top 30. On the workforce front, they aim to increase the number of skilled workers in the manufacturing sector from 18% to 30%.

Table 2 provides a summary of policies and mechanisms introduced to incentivize technology adoption specifically for the manufacturing sector.

Table 2: Government policies and grants for IR 4.0 in the manufacturing sector under Industry 4WRD led by MITI

Implementation
Through loans: 1. Soft Loan Scheme for Automation & Modernization (MIDF) a. Manufacturing firm with min 51% equity held by Malaysians b. Financing amount: RM50,000 – RM20 mil c. Interest rate: 4% (SME); 5% (non-SME) 2. Industry Digitalization Transformation Fund by BPMB a. Min 40% Malaysian owned b. Financing amount: up to RM 200 mil c. Interest rate subsidy: 2% p.a. Through grants: 1. Intervention fund (MIDA) a. Matching grant of 70:30 b. Up to RM500,000 c. For minimum 60 SMEs which have undertaken RA 2. Domestic Investment Strategic Fund (MIDA) a. Matching grant of 60:40 b. Local companies which have undertaken RA 3. Automation Capital Allowance (MIDA) a. 200% allowance on the first RM4 mil/ RM 2 mil expenditure incurred within 5 years (labour intensive industries/ other industries) 4. Digital Transformation Acceleration Program (MDEC) a. Pilot Grant will provide a matching grant (1:1) to implement the digital transformation pilot.

One key tool used by the MITI is the Readiness assessments (RA), carried out by the Malaysian Productivity Corporation and other agencies for SMEs to help assess their present capabilities and readiness to adopt IR 4.0 technologies. The assessments will then be used to produce practical strategies and plans to help these companies move forward with their adoption of tech. The Ministry of International Trade and Industry (MITI) achieved the target in the implementation of the RA programme for 2019, with the participation of 508 SMEs in this programme. For 2020, the government was targeting 373 SMEs to undergo this programme. The total number of SME and micro manufacturing firm in 2020 is nearly 60,000 firms (DOSM, n.d) - thus only a small number has been able to go through the readiness assessment.

Between 2019 and 2020, RM 35 billion has also been allocated to skills training, manufacturing process improvements and technology applications in the area of IR4.0 and as of November 2020, 138 Intervention fund applications had been received by the government, whilst 63 SMEs have received the matching grants, according to Deputy International Trade and Industry Minister Datuk Lim Ban Hong (MIDA, 2020). As of May 31, 2022, MIDA has also approved 444 applications for the Automation Capital Allowance (The Star 2022).

Beyond the few news reports available, the performance of the various IR 4.0 adoption policies has not been made publicly available, which reduces the transparency in knowing the achievements for the policy.

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