Has Digitalisation Mitigated the Impact of Covid-19 on the Manufacturing Sector's Performance?

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Abstract

The Covid-19 pandemic brought many businesses to a standstill as international travel restriction was imposed across countries in addition to a national lockdown. Firm performances were depressed due to reduced order and output. This study examines whether digitalization has mitigated the negative impact of the Covid-19 pandemic on Malaysia's manufacturing sector. Using sales as the performance yardstick of 24 industrial sectors from January to December 2020, our result shows that manufacturing sales performance was negatively related to the Covid-19 pandemic. However, the adverse impact of Covid-19 was mitigated with a higher level of digitalization. The mitigating role of digitalization remains robust in further analysis. This study has managed to quantify the mitigating effect of Covid-19 on manufacturing sectors. As a policy implication, the government should expedite the introduction of the 5G network, promote digital adoption across all sectors to ensure business continuity and provide an effective response mechanism in any pandemic or crisis.

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I. Introduction

The outbreak of the Covid-19 pandemic brought conventional economic activities, such as manufacturing activities, to a standstill. Global manufacturing production growth has decreased since 2019 due to the ongoing trade dispute between the United States and China (UNIDO, 2020). However, the slowdown is exacerbated by the outbreak of the Covid-19 pandemic in the year 2020. Based on the UNIDO (2020) statistics, global manufacturing production recorded a negative 4.1% growth in 2020. Across the regions, European industrialized countries recorded the highest fall in manufacturing production (-7.6%), followed by Latin America (-7.3%), North America (-6.7%), Africa (-5.4%) and East Asia (-4.7%). Implementing a national lockdown policy to curb Covid-19 transmission has halted manufacturing activity, whereby factories are not allowed to operate during the lockdown period. Consequently, this negatively affects the output and sales performance of the manufacturing industry. The adverse impact of the Covid-19 pandemic on manufacturing sector performance has been widely documented in the existing literature (Bauer et al., 2020; Cai and Luo, 2020; Chakraborty and Biswas, 2020; Harris et al., 2020; Kaur, 2021; Telukdarie et al., 2020; Wen et al., 2021; Zhang, 2021).

Against this background, international organizations such as the World Bank (World Bank, 2020), UNCTAD (UNCTAD, 2021) and International Monetary Fund (Njoroge and Pazarbasioglu, 2020) suggest that digitalization is the solution to mitigate the negative impact of the Covid-19 pandemic on the sectoral performance. Practically, digital technologies such as digital payments, e-commerce and robots would help businesses cope with national lockdown measures, ensuring business continuity and offsetting the adverse impact of the pandemic. The theoretical argument for the mitigating role of digitalization is proposed by Guo et al. (2020). Specifically, digitalization would offset the adverse impact of the Covid-19 pandemic on firms' performance by providing effective crisis response strategies to cope with the pandemic.

As such, highly digitalized firms tend to have greater dynamic capabilities in sensing the crisis, seizing new opportunities, and reconfiguring resources to cope with the crisis. This strategy would result in effective crisis response strategies and offset the pandemic's adverse impact on firms' performance. Notably, the mitigating role of digitalization is further highlighted in the empirical study by Belhadi et al. (2021), in which digital adoption is essential in helping firms overcome the challenges imposed by the Covid-19 pandemic and subsequently sustain their business operation.

Malaysia is one of the countries seriously affected by the Covid-19 pandemic. As of 31 December 2020, Malaysia has recorded a total of 3491 Covid-19 cases per million population, far surpassing the neighbouring countries, such as Thailand (102 cases per million population), Brunei (358 cases per million population), Vietnam (15 cases per million population) and Indonesia (2717 cases per million population)[4]. The spike in Covid-19 cases has disturbed Malaysia's economic performance, as shown by the 5.6% contraction in the annual GDP growth rate in 2020. This number is distressing given that Malaysia's full-year growth rate is the weakest since a 7.4% contraction in the 1997/98 Asian financial crisis. In line with the sluggish economic outlook, the manufacturing sector recorded a negative 2.6 per cent year-on-year growth in 2020. Likewise, manufacturing sales recorded a downturn of 2.2 per cent in the same year. Following the Movement Control Order (MCO) implementation, the manufacturing

[4] The Covid-19 figures are obtained from the *Our World In Data* database.

sector experienced the largest decline in sales in April 2020 monthly, with a negative 33 percent growth rate compared to the preceding month.

The manufacturing sector is an important contributor to Malaysia's economic performance. In 2019, the sector contributed 21.4% to Malaysia's GDP. Meanwhile, in 2020, despite the onset of the Covid-19 pandemic, the manufacturing sector remained the important GDP contributor at 22.3%. Given the economic importance of the manufacturing sector, policymakers must undertake various measures to help manufacturers cope with the pandemic, thereby ensuring sustainable growth for the sector.

As indicated above, international organizations have repeatedly emphasized digitalization as the key to coping with the challenges imposed by the pandemic. However, to the best of the authors, there is no empirical study quantifying digitalization's mitigating effect in Malaysia's context. The finding is important as it would provide alternative policy options to the Malaysian government in helping the local manufacturers to cope with the Covid-19 pandemic. Moreover, for the manufacturers, the finding would suggest alternative crisis response strategies to help them to sustain their business operations during the pandemic. Accordingly, this study investigates whether digitalization mitigates the negative impact of the Covid-19 pandemic on Malaysia's manufacturing sector performance.

Based on a balanced panel data of 24 sub-sectors in Malaysia's manufacturing sector from January 2020 to December 2020, the empirical result shows that the manufacturing sales performance is negatively associated with the Covid-19 pandemic. Digitalization is essential in mitigating the negative relationship. Specifically, the Covid-19 pandemic significantly and adversely impacts manufacturing sales performance if digitalization is low. However, the negative effect diminishes with a rising level of digitalization. Moreover, the mitigating effect of digitalization remains consistent in a series of robustness checks.

Based on the above findings, this study contributes to the existing literature in two aspects. First, the present analysis validates the role of digitalization in offsetting the adverse impact of Covid-19 on manufacturing sales performance. A similar study has been conducted in China (Guo et al., 2020) and a group of developed countries (Belhadi et al., 2021), but there is a dearth of research focusing on Malaysia. Second, this study puts forth alternative model specifications by providing the marginal effect of the Covid-19 pandemic on manufacturing sales performance at various levels of digitalization. This study complements and expands the previous study by Guo et al. (2020) and Belhadi et al. (2021), which employed a survey method to quantify the mitigating effect of digitalization.

In addition to the above scholarly contributions, this study has direct implications for Malaysia's policymakers. The finding supports the various measures undertaken by the Malaysian government under the Malaysia Digital Economic Blueprint to accelerate digital adoption in the country. Digitalization has been found to overcome the challenges imposed by the Covid-19 pandemic. Therefore the finding indicates that digital technologies should cover all the manufacturers in Malaysia, thereby helping them cope with the crisis effectively and subsequently preserve the manufacturing sector performance.

Furthermore, for the manufacturers, this study proposes an alternative crisis response strategy to help them to sustain their operations during the Covid-19 pandemic. The result indicates that manufacturers should actively pursue digitalization in the workplace. For instance, adopting digital technology such as remote robots allows manufacturers to operate remotely following a national lockdown, thereby ensuring the continuation of manufacturing production. Furthermore, e-commerce provides manufacturers with alternative platforms to market their products and services, preserving sales performance. Digitalization can be regarded as the universal crisis response strategy for effectively helping Malaysia's manufacturers cope with the Covid-19 pandemic.

This paper is arranged as follows. Section II reviews the theoretical argument on digitalization in mitigating the effect of the pandemic. Section III describes the data, model and methodology used. Section IV presents baseline estimation results followed by the robustness checks in section V. Section VI concludes the study and makes policy recommendations.

II. Theoretical review

The theoretical argument for the mitigating role of digitalization is based on the study by Guo et al. (2020). Digitalization would offset the adverse impact of the Covid-19 pandemic on firms' performance by providing effective crisis response strategies to cope with the pandemic. Specifically, highly digitalized firms are associated with greater dynamic capabilities in sensing the crisis, seizing new opportunities, and reconfiguring resources to cope with the crisis. This digitalization would result in effective crisis response strategies and offset the adverse impact on firm performance due to the pandemic.

Dynamic capabilities refer to the firms' capability to build, integrate and reconfigure resources when coping with a rapidly changing environment (Treece et al., 1997; Treece, 2007; 2012). This perspective is the key to formulating effective crisis response strategies for firms. Firms with dynamic capabilities are more likely to adapt to the changing environment and sustain company operations during a crisis (Eisenhardt and Jeffrey, 2000; Lin and Wu, 2014).

In the context of a crisis, dynamic capabilities involve three dimensions, namely the capability of sensing the crisis, the capability of seizing new opportunities in the crisis and the capability of reconfiguring resources to cope with the crisis (Treece, 2007; Ballesteros et al., 2017; Guo et al., 2020). The first dimension indicates the ability to sense or understand the crisis on time. Logically, firms cannot predict the arrival of unprecedented events, such as the outbreak of the Covid-19 pandemic. However, with dynamic capabilities, firms can gauge the possible implication of the pandemic on the company operation, such as production interruption, supply chain distortion and order cancellation. Hence, firms would better perceive the crisis and develop comprehensive strategies to overcome the challenges imposed by the pandemic.

The second dimension posits that firms with dynamic capabilities are more likely to seize new business opportunities and provide an alternative business model to help the company sustain itself in a crisis. In application to the Covid-19 outbreak, the pandemic has resulted in the closure of physical stores. Implementing social distancing measures led consumers to switch from offline to online purchases. This switch in consumer behaviour created new business opportunities for firms, particularly e-commerce. Therefore, firms with dynamic capabilities would leverage the online platform to market their products and services, thereby preserving firms' sales performance during pandemic periods.

The third dimension illustrates that firms with dynamic capabilities can integrate internal and external resources to cope with a crisis. In application to the Covid-19 outbreak, the pandemic has resulted in plant closure, especially in the manufacturing sector, to curb the virus transmission. The operation shutdown is costly and hampers the firms' financial position.

Hence, firms with dynamic capabilities are more likely to employ external resources to continue business operations. For instance, firms may equip employees with digital technologies such as remote robots to conduct production activities. These robots allow the continuation of production activity despite the shutdown of the plant. Subsequently, they offset the revenue losses caused by the pandemic.

Meanwhile, digitalization refers to organizational transformation through adopting digital technologies (Sebastian et al., 2017; Vial, 2019; Guo et al., 2020). Digitalization has been widely perceived as the key to sustainable development for business enterprises (OECD, 2014). Digitalization, particularly the application of big data analysis, enables firms to predict the changing environment to some extent, thereby better gauging the country's future economic prospects. This digital application assists the firm in designing short- and long-term strategies to sustain the company amid future economic uncertainty. Moreover, digitalization allows firms to expand their consumer market to venture into a new business model, such as the digital business. Furthermore, digitalization enables robots in the production process, improving production efficiency and allowing firms to achieve greater economies of scale.

In this study, notably, digitalization interferes with all the firms' dynamic capabilities dimensions. In particular, digitalization enhances firms' dynamic capabilities by responding better to the Covid-19 pandemic and subsequently preserving firms' performance (Guo et al., 2020). In other words, digitalization is expected to offset the adverse impact of the Covid-19 pandemic on firms' performance.

Digitalization would enhance firms' capability to sense the crisis for the first dimension in dynamic capabilities. Digitalization enables firms to identify the spread of Covid-19, thereby providing an early indication of the possible implication of the pandemic on firms' performance. Subsequently, early preparation can be conducted to cope with the pandemic. For instance, big data analysis would help firms predict environmental changes to some extent and allow them to perceive the pandemic better (George et al., 2014). The analysis will enable the firms to formulate strategies to cope with the pandemic.

Next, in the second dimension, firms can better seize business opportunities with the help of digital technology. In application to the Covid-19 outbreak, digitalization enables firms to venture into a digital business model by providing an online platform to market their products and services. This digital platform expands the consumer market and provides a constant revenue stream to the company, offsetting the revenue loss due to the closure of physical stores during the pandemic.

In the third dimension, digitalization expands firms' resources to respond to crises. Applying to the manufacturing sector, the national lockdown policy that stops manufacturing would impose various challenges to the manufacturers, such as staff shortage, production disruption, and delay in launching new products. In this regard, digital technology, such as remote robots, would help manufacturers continue their output production. As such, employees are equipped with remote control robots to perform their daily routines in the factory. Hence, this ensures the continuation of manufacturing activity despite the closure of the plant. Thus, manufacturers with a high degree of digitalization are more likely to quickly reshape their operations and subsequently minimize the adverse impact of the pandemic.

As indicated by the above theoretical arguments, it can be argued that digitalization plays an important role in the relationship between the Covid-19 pandemic and firms' performance. In particular, the Covid-19 pandemic is conjectured to depress firms' performance by reducing output produced and purchase orders. Digitalization would mitigate this adverse effect by providing effective crisis response strategies to cope with the pandemic. Specifically, highly digitalized firms are associated with greater dynamic capabilities in sensing the crisis, seizing new opportunities in the crisis period and reconfiguring resources to cope with the crisis. This digitalization process would result in effective crisis response strategies and offset the pandemic's adverse impact on firms' performance and vice versa.

III. Data and empirical model

Data

This study utilizes balanced panel data of 24 sub-sector (as shown in Appendix 1) in the Malaysian manufacturing industry from January 2020 to December 2020. The main dependent variable in this study is the monthly growth rate of manufacturing sales (*SALESMoM*), a proxy for the Malaysian manufacturing sector performance. The monthly manufacturing sales (*SALES*) are obtained from the Department of Statistics Malaysia (DOSM) and subsequently transformed into a monthly growth rate by using the following formula:

$$SALESMoM_{it} = \frac{SALES_{it} - SALES_{it-1}}{SALES_{it-1}} * 100 \quad (1)$$

Next, the Covid-19 pandemic is proxy by the total Covid-19 cases per million population (*COVID*), and digital adoption (*DIGITAL*) is proxy by the number of fixed broadband subscribers of Telekom Malaysia. There are two reasons for choosing this proxy. First, Telekom Malaysia is the major internet service provider in Malaysia. Therefore, the number of fixed broadband subscribers will likely capture a broad range of internet users than other internet services provider companies such as Maxis, Digi, Celcom, and U Mobile. Hence, it can be expected that Telekom Malaysia's number of fixed broadband subscribers will likely capture the pace of digitalization in Malaysia. Second, broadband penetration has been recognized by the World Bank as an important source of growth for a country (Minges, 2016). As such, broadband enables services such as cloud computing and mobile apps, facilitating innovation across various sectors of the economy. In application to this study, the broadband internet would facilitate innovation and productivity in the manufacturing sector by digitalizing the production process. Digitalization enables robots and facilitates production, allowing projects to move faster and manufacturers to receive more orders. As a result, digitalization enables manufacturers to practice economies of scale, improving output and company performance.

However, the number of fixed broadband subscribers of Telekom Malaysia is available on a quarterly frequency. Hence, this study employs the cubic spline interpolation method to convert the quarterly subscribers into monthly frequency. This interpolation method is detailed in Granville (2005) and is widely adopted in empirical studies to overcome data unavailability (Bathia and Bredin, 2013; Isabel, 2017; Shaharuddin et al., 2018).

Apart from the variables used in the baseline estimation, in the robustness check section, additional control variables such as gross export (*EXPORT*), gross import (*IMPORT*) and exchange rate (*MYRUSD*) are included to avoid omitted variables bias in the model. The inclusion of the variables allows the model to capture the impact of external demand, internal consumption and exchange rate variation on manufacturing sales, respectively.

Next, alternative measures for the Covid-19 pandemic, digital adoption and manufacturing sales, namely new Covid-19 cases per million population (*COVIDNEW*), internet banking penetration rate (*IB*) and yearly growth rate of the manufacturing sales (*SALESYoY*), are included in the model. All the variables used in the baseline estimation and robustness check are shown in Table 1.

Table 1: List of variables

Variables	Description	Unit of measurement
Variables used in the baseline model		
SALESMoM	The monthly growth rate of manufacturing sales	Month-on-month %
COVID	Total Covid-19 cases	Per million population
DIGITAL	Telekom Malaysia's fixed broadband subscriber	Thousands
Variables used in robustness checks		
EXPORT	Gross export	Million MYR
IMPORT	Gross import	Million MYR
MYRUSD	Dollar to Ringgit exchange rate	Exchange rate
COVIDT	New Covid-19 cases	Per million population
IB	Internet banking penetration rate	% of the total population
SALESYoY	Yearly growth rate of manufacturing sales	Year-on-year %

Notes:

1. Manufacturing sales data is obtained from the Department of Statistics (DOSM), Malaysia
2. Covid-19 data is obtained from the Our World In Data database. Website: https://ourworldindata.org/coronavirus/country/malaysia
3. The number of fixed broadband subscribers is obtained from Telekom Malaysia's annual report.
4. Internet banking penetration rate, gross export, gross import and exchange rate are obtained from the Monthly Statistics Bulletin Bank Negara Malaysia (BNM).

Empirical Model

The empirical model used to examine the impact of the Covid-19 pandemic and digital adoption on manufacturing sales is shown in Eq. (2).

$$SALESMoM_{it} = \beta_0 + \beta_1 COVID_t + \beta_2 DIGITAL_t + v_i + \varepsilon_{it} \quad (2)$$

where i is the sectoral index, t is the month index, *SALESMoM* represents the monthly growth rate of the manufacturing sub-sector sales value, and *COVID* represents the total Covid-19 cases per million population. *DIGITAL* denotes digital adoption, proxy by the number of fixed broadband subscribers of Telekom Malaysia. The v_i represents the sector-specific effect and ε_{it} represents the error term.

Both Covid-19 and digital adoption measures are not available by sectoral level, so the aggregate value is included in the model. However, using aggregate value can capture the impact of Covid-19 and digital adoption on manufacturing sales performance. For instance, higher Covid-19 cases induce the Malaysian government to implement a national lockdown policy to curb virus transmission. Consequently, this halts manufacturing activity, whereby factories are not allowed to operate during the lockdown period. This, in turn, negatively affects the sales performance of the manufacturing industry.

For the digital adoption measure, the higher number of fixed broadband subscribers indicates a greater degree of internet penetration rate in the country, thereby facilitating manufacturing sales performance. From the consumer perspective, internet use allows them to purchase through e-commerce. This online system ensures consistent demand for manufacturers' goods amid the closure of the physical store. For manufacturers, the internet allows firms to venture into a digital business model by providing an online platform to market their products and services. This approach would expand the consumer market and provide a constant revenue stream to the company, thereby offsetting the revenue loss due to the closure of physical stores during the pandemic. More importantly, the use of the internet, particularly high-speed internet, such as a 5G network, allows firms to deploy remote robots in the factory. Remote robots enable employees to perform their daily routine in the factory, thereby ensuring the continuation of manufacturing activity despite the plant's closure. This approach facilitates the output produced and sales performance of the manufacturing sector.

The estimated coefficients β_1 and β_2 provide the impact of the Covid-19 pandemic and digital economy on manufacturing sales. Given that this study focuses on assessing whether digital adoption mitigates the sales-deteriorating effect of the Covid-19 pandemic, Eq. (2) is extended to incorporate the interaction between *COVID* and *DIGITAL*, as shown in Eq. (3).

$$SALESMoM_{it} = \beta_0 + \beta_1 COVID_t + \beta_2 DIGITAL_t + \beta_3 COVID_t * DIGITAL_t + v_i + \varepsilon_{it} \quad (3)$$

Including the interaction term, *COVID*DIGITAL* enables identifying the impact of Covid-19 on manufacturing sales at the varying pace of digital adoption in Malaysia. The marginal effect of Covid-19 on manufacturing sales depends on β_3 after adding the interaction term, as in Eq. (4). That is:

$$\frac{\partial SALESMoM_{it}}{\partial COVID_t} = \beta_1 + \beta_3 DIGITAL_t \quad (4)$$

The Fixed Effect (FE) estimator was used to estimate Eq. (2) and Eq. (3). There are two reasons for choosing this estimator. First, the FE estimator includes the sector-specific effect in the estimation to control for heterogeneity across different manufacturing sub-sectors. The Pooled OLS (POLS) estimator assumes homogeneity across the cross-section unit. This homogeneity is a strict assumption, given that the sales value will likely differ across the sub-sectors. Hence, the FE estimator is deemed to provide an unbiased estimate compared to the POLS estimator. Second, compared to the Random Effect (RE) estimator, the FE estimator is consistent and efficient in the presence of a non-zero correlation between explanatory variables and the sector-specific effect. In particular, the pace of digital adoption is likely to vary across different sub-sectors. As such, sectors which are capital intensive tend to have a higher degree of digital adoption as compared to their intensive labour counterparts. Therefore, the *DIGITAL* variable will likely correlate with the sector-specific effect or endogeneity problem. In this regard, the FE estimator applies within transformation to filter out the sector-specific effect, mitigating endogeneity concerns and providing correct inferences on the relationship between digital adoption and manufacturing sales. Stata version 14 was used to perform all data analysis. Robust standard error was computed to preclude heteroscedasticity and autocorrelation in the error term.

IV. Empirical results

Descriptive statistics

Table 2 shows the descriptive statistics for all the variables used in this study. The manufacturing sector in Malaysia experienced a positive average monthly sales growth rate of 0.183 percent in the year 2020. However, the yearly growth rate of manufacturing sales was negative 7.3 percent, indicating that the outbreak of the Covid-19 pandemic has halted the manufacturing sector's performance compared to the preceding year. Next, on average, the total Covid-19 cases stood at 682 cases per million population, far surpassing neighbouring countries, such as Thailand (41 total Covid-19 cases per million population), Brunei (328 total Covid-19 cases per million population) and Vietnam (6 total Covid-19 cases per million population). Meanwhile, the average number of Telekom Malaysia's fixed broadband subscribers stood at 2253 thousand in 2020.

Table 2: Descriptive statistics

Variable	Mean	Std. dev	Obs
SALESMoM	0.183	51.506	264
COVID	682.439	1006.935	288
DIGITAL	2253.260	56.916	288
EXPORT	81726.330	9927.055	288
IMPORT	66346.260	5501.961	288
MYRUSD	4.198	0.103	288
COVIDNEW	12.258	22.646	288
IB	105.890	4.749	288
SALESYoY	-7.309	23.660	288

Notes:

1. Sample period: January 2020-December 2020.
2. Given that the manufacturing sales are measured in monthly growth rate. Hence, the data point for January 2020 effectively drops out for all 24 sub-sectors.

Baseline results

From Table 3, column 1 shows the estimation results for Eq. (2). In contrast, columns 2 to 5 outline the estimation results for the interaction model (Eq. (3)). By focusing on column 1, it can be observed that the estimated coefficients for Covid-19 cases (*COVID*) is negative and statistically significant at a 1 per cent level. As observed, an additional 1 case increase in the total Covid-19 cases per million Malaysian population is associated with a 0.013 per cent reduction in the manufacturing sales performance. The effect is substantial, given that Malaysia recorded 3491 Covid-19 cases per million of the population in December 2020. The results indicate that the Covid-19 pandemic suppresses the manufacturing sales performance in Malaysia.

The result is consistent with the empirical finding in other countries, such as South Africa (Telukdarie et al., 2020), Bangladesh (Chakraborty and Biswas, 2020), Pakistan (Kaur, 2021), China (Cai and Luo, 2020 and Wen et al., 2021), the United Kingdom (Harris et al., 2020; OECD, 2020), Japan (Zhang, 2021), New Zealand (Stats NZ, 2020) and the United States (Bauer et al., 2020). These studies found that the Covid-19 pandemic has a dampening impact on the country's manufacturing sector performance.

Besides, the finding is in line with the survey results published by the Federation of Malaysian Manufacturers (FMM). As such, the Federation of Malaysian Manufacturers (FMM)-Malaysian Institute of Economic Research (MIER) Business Conditions Index recorded a slump in manufacturing activity and local and export sales in the first half of 2020 (Federation of Malaysian Manufacturers, 2020a). Furthermore, the industry survey found that almost all businesses saw revenue drop in the first half of 2020, with 82 per cent of the respondents surveyed reporting a decrease in income while 80 per cent said their profitability plunged. Similarly, in the second half of 2020, most of the indicators under the Business Conditions Index remained below the 100-point threshold level of optimism, indicating that the overall business condition in the Malaysian manufacturing sector had remained subdued (Federation of Malaysian Manufacturers, 2020b).

Next, digital adoption (*DIGITAL*) positively and significantly influences manufacturing sales performance. The result indicates the importance of digital adoption in facilitating manufacturing sales performance. Notably, the finding is in line with the empirical literature (Dalenogare et al., 2018; Lin et al., 2019; Buchi et al., 2020; Falentina et al., 2020; Martin-Pena et al., 2020; Chauhan et al., 2021), which argued that digital adoption is the key for improving manufacturing sector performance. Moreover, the finding supports the numerous policy measures undertaken by the Malaysian government under the Malaysia Digital Economic Blueprint to accelerate digital adoption in the country.

Turning to the focus of this study. Column 2 of Table 3 shows the mitigating effect of digital adoption. As noted by Brambor et al. (2006), it is inappropriate to interpret the coefficients of Covid-19 (*COVID*) and digital adoption (*DIGITAL*) if the model contains an interaction term (*COVID*DIGITAL*), as the former captures the effect of Covid-19 pandemic on sales performance only if the digital adoption is equal to zero. The latter provides the effect of digital adoption on sales performance only if the Covid-19 cases are equal to zero. The interaction term (*COVID*DIGITAL*) is positive and significant at the 1 per cent level, implying that digital adoption mitigates the negative effect of the Covid-19 pandemic on manufacturing sales performance.

Following the suggestion by Brambor et al. (2006), the marginal effect of the Covid-19 pandemic on manufacturing sales performance is computed at different levels of digital adoption to exhibit its mitigating effect. The marginal effect diagram shows the role of digital adoption in mitigating the adverse effect of the Covid-19 pandemic on manufacturing sales performance (Figure 1). As observed, the Covid-19 pandemic has a negative and significant impact on sales performance if the digital adoption is at the minimum level (2182 thousand of Telekom Malaysia's fixed broadband subscribers). The negative effect corresponds to the intercept of the solid marginal effect line (-0.065%). However, the negative impact of the Covid-19 pandemic on manufacturing sales performance diminishes with the rising level of digital adoption. When digital adoption is at the maximum level (2366 thousand Telekom Malaysia's fixed broadband subscribers), the negative impact is reduced to -0.019%. This outcome is equivalent to a 3.5 times reduction in the sales-deteriorating effect of the Covid-19 pandemic. The substantial effect highlights the important role of digitalization in offsetting the sales-deteriorating effect of the Covid-19 pandemic.

The finding on the mitigating effect of digital adoption is in line with the theoretical argument by Guo et al. (2020), whereby digitalization is essential in improving firms' dynamic capabilities and providing effective response strategies to cope with the Covid-19 pandemic. Thus, this mitigates the adverse impact of the Covid-19 pandemic and preserves firms' performance. Empirically, the finding concurs with the Belhadi et al. (2021) study, in which digital adoption is essential in helping firms overcome the challenges imposed by the Covid-19 pandemic and sustain their business operation.

Next, Columns 3 to 5 in Table 3 for robustness check purposes. In particular, additional control variables are added into the interaction model Eq. (3) to avoid omitted variable bias. As mentioned earlier, inferences will be made based on the marginal effect estimate instead of the coefficient of the interaction term. However, the marginal effect diagram will not be plotted for the estimation result in columns 3 to 5 due to space constraints but is available upon request. Alter, the marginal effect of the Covid-19 pandemic on manufacturing sales performance was computed for the digital adoption variable's minimum, mean and maximum values. A similar approach is used for the subsequent robustness checks. Notably, the mitigating effect of digital adoption remains consistent in all the specifications. As such, the adverse impact of the Covid-19 pandemic reduces with a higher degree of digital adoption. Thus, the baseline result is robust and not influenced by additional variables in the model.

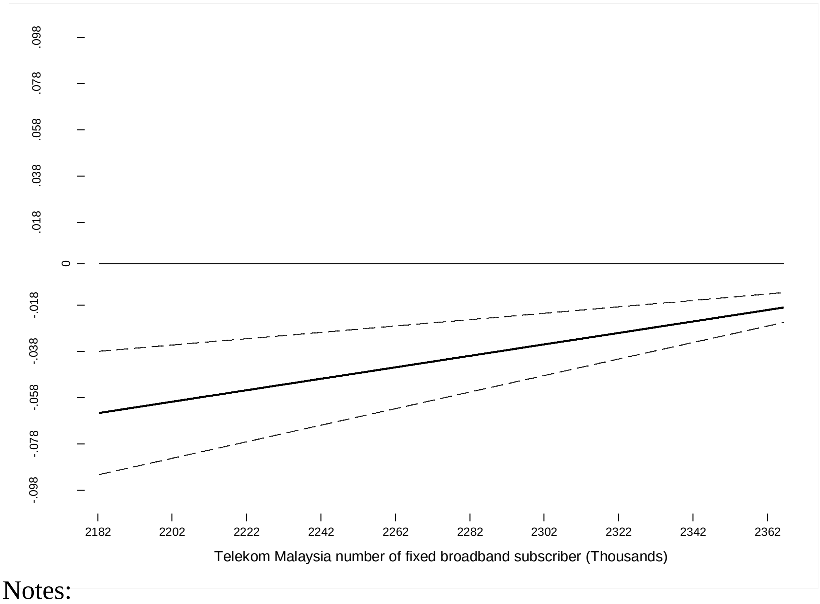
Table 3: Baseline estimation result

	1	2	3	4	5
Constant	-692.582***	-965.333***	-1162.397***	2261.935***	-2389.054***
	(128.422)	(197.423)	(261.676)	(444.396)	(406.714)
COVID	-0.013***	-0.606***	-0.243**	-1.520***	-0.988***
	(0.002)	(0.164)	(0.086)	(0.310)	(0.203)
DIGITAL	0.311***	0.437***	0.233***	0.758***	0.690***
	(0.058)	(0.090)	(0.050)	(0.144)	(0.122)
COVID*DIGITAL	-	0.0001***	0.0001**	0.0006***	0.0004***
		(0.0000)	(0.0000)	(0.0001)	(0.0001)
LnEXPORT	-	-	57.458**	-	-
			(21.314)		
LnIMPORT	-	-	-	-355.565***	-
				(66.365)	
LnMYRUSD	-	-	-	-	596.200***
					(109.876)
Marginal effect					
Minimum	-	-0.065***	-0.031***	-0.135***	-0.094***
		(0.016)	(0.009)	(0.028)	(0.019)
Mean	-	-0.047***	-0.024***	-0.089***	-0.065***
		(0.011)	(0.006)	(0.018)	(0.013)
Maximum	-	-0.019***	-0.013***	-0.017***	-0.019***
		(0.004)	(0.002)	(0.004)	(0.004)
No. Subsector	24	24	24	24	24
Observation	264	264	264	264	264

Notes:

1. *, ** and *** denotes statistically significant at 10%, 5% and 1% level, respectively.
2. Values in parentheses are robust standard errors. Ln denotes the natural logarithm.

Figure 1: Marginal effect of the Covid-19 cases on manufacturing sales.



Notes:

1. The figure provides the marginal effect (solid line) and its 90% confidence interval (dotted lines).
2. The above marginal effect diagram is plotted based on FE robust estimator in Table 3, column 2.

V. Robustness checks

Alternative measures of Covid-19 cases

This study aims to examine the role of digitalization in mitigating the sales-deteriorating effect of the Covid-19 pandemic. Hence, a series of robustness checks were conducted to ensure the reliability of statistical inferences drawn from the model with an interaction term (Eq. (3)).

Table 4 shows the robustness check results with alternative measures of Covid-19 cases, namely the new Covid-19 cases per million population (*COVIDNEW*). Notably, the mitigating effect of digitalization is consistent in all the specifications. The negative influence of the Covid-19 pandemic on manufacturing sales performance deteriorates with a higher level of digital adoption. The outcome indicates that the baseline finding is robust and not influenced by alternative measures of Covid-19 cases.

Table 4: Robustness check with new Covid-19 cases per million population

	1	2	3	4
Constant	-715.718***	-1141.871***	2676.232***	-1556.932***
	(134.301)	(267.017)	(522.092)	(262.979)
COVIDNEW	-27.769***	-25.341***	-17.951***	-29.079***
	(6.049)	(5.366)	(4.804)	(6.132)
DIGITAL	0.322***	0.198***	0.414***	0.443***
	(0.060)	(0.034)	(0.076)	(0.074)
COVIDNEW*DIGITAL	0.011***	0.010***	0.007***	0.012***
	(0.003)	(0.002)	(0.002)	(0.003)
LnEXPORT	-	62.343***	-	-
		(21.045)		
LnIMPORT	-	-	-325.383***	-
			(60.914)	
LnMYRUSD	-	-	-	394.009***
				(87.655)
Marginal effect				
Minimum	-2.679***	-2.432***	-1.466***	-2.692***
	(0.564)	(0.495)	(0.410)	(0.566)
Mean	-1.863***	-1.687***	-0.930***	-1.832***
	(0.386)	(0.337)	(0.268)	(0.385)
Maximum	-0.560***	-0.497***	-0.074	-0.462***
	(0.107)	(0.089)	(0.051)	(0.101)
No. Subsector	24	24	24	24
Observation	264	264	264	264

Notes:
1. *, ** and *** denotes statistically significant at 10%, 5% and 1% level, respectively.
2. Values in parentheses are robust standard errors. Ln denotes the natural logarithm.

Alternative measures of digital adoption

This robustness check considers an alternative proxy for digital adoption: the internet banking penetration rate. A high degree of internet banking penetration rate implies greater usage of e-commerce to purchase goods and services. Subsequently, this would induce firms or businesses to venture into digital business to expand their consumer market. Arguably, a higher internet banking penetration rate is expected to be associated with a higher degree of digital adoption in the economy.

Table 5 shows the estimation result using the internet banking penetration rate (*IB*). Consistent with the baseline finding, the marginal effect estimate shows that the negative impact of the Covid-19 pandemic on manufacturing sales performance reduces with the rising internet banking penetration rate.

Table 5: Robustness check with internet banking penetration rate

Covid-19 measure	Total Covid -19 cases per million population	New Covid -19 cases per million population
	1	2
Constant	-576.477***	-390.044***
	(110.684)	(71.507)
COVID	-1.923***	-
	(0.429)	
COVIDNEW	-	-28.663***
		(6.679)
IB	5.743***	3.749***
	(1.109)	(0.688)
COVID*IB	0.017***	-
	(0.004)	
COVIDNEW*IB	-	0.251***
		(0.059)
Marginal effect		
Minimum	-0.255***	-3.909***
	(0.056)	(0.888)
Mean	-0.130***	-2.059***
	(0.029)	(0.456)
Maximum	-0.019***	-0.409***
	(0.004)	(0.078)
No. Subsector	24	24
Observation	264	264

Notes:

1. *, ** and *** denotes statistically significant at 10%, 5% and 1% level, respectively.
2. Values in parentheses are robust standard errors. Ln denotes the natural logarithm.

An alternative measure of manufacturing sales

The earlier analysis employed the monthly growth rate of manufacturing sales as the proxy for manufacturing sector performance. This section uses the yearly growth of manufacturing sales to gauge the impact of the Covid-19 pandemic on performance in the manufacturing sector. The results indicate that digitalization plays an important role in offsetting the adverse impact of the Covid-19 pandemic on sales performance. Hence, the baseline finding on the mitigating effect of digital adoption is consistent and not influenced by different sales performance measures.

Table 6: Robustness check with a yearly growth rate of manufacturing sales

Covid-19 measure	Total Covid -19 cases per million population		New Covid -19 cases per million population	
	1	2	3	4
Constant	-658.428***	-148.995*	-273.720***	-62.890**
	(99.460)	(75.111)	(39.268)	(29.916)
COVID	-1.019***	-4.798*	-	-
	(0.109)	(2.580)		
COVIDNEW	-	-	-2.181***	-15.177***
			(0.247)	(2.742)
DIGITAL	0.297***	-	2.776***	-
	(0.045)		(0.391)	
IB	-	0.064*	-	0.530*
		(0.034)		(0.287)
COVID*DIGITAL	0.0004***	-	-	-
	(0.0000)			
COVID*IB	-	0.0021*	-	-
		(0.0011)		

COVIDNEW*DIGITAL	-	-	0.019*** (0.002)	-
COVIDNEW*IB	-	-	-	0.136*** (0.024)
Marginal effect				
Minimum	-0.089*** (0.009)	-0.322 (0.246)	-0.277*** (0.031)	-1.781*** (0.356)
Mean	-0.058*** (0.006)	-0.177 (0.172)	-0.135*** (0.015)	-0.779*** (0.179)
Maximum	-0.009*** (0.002)	0.056 (0.062)	-0.008*** (0.001)	0.114*** (0.037)
No. Subsector	24	24	24	24
Observation	288	288	288	288

Notes:
1. *, ** and *** denotes statistically significant at 10%, 5% and 1% level, respectively.
2. Values in parentheses are robust standard errors.

Control for seasonal variation

Early analysis omits the seasonal dummy. Seasonality might prevail in manufacturing sales, given that consumer demand is driven by seasonal factors such as holidays and fiscal timelines (year-end). Hence, omitting a seasonal dummy might result in variable bias and affect the estimate's accuracy. Accordingly, this study re-estimates the interaction model (Eq. 3) by including the seasonal dummy as an additional explanatory variable. Table 7 shows the corresponding result. The estimated coefficients for the seasonal dummy are not reported but are available upon request to conserve space. Overall, the mitigating effect of digital adoption remains consistent despite including a seasonal dummy.

Table 7: Robustness check by controlling for seasonal variation (month dummy).

Covid-19 measure	Total Covid -19 cases per million population		New Covid -19 cases per million population	
	1	2	3	4
Constant	-301.152*** (89.603)	-129.475*** (38.637)	-682.926** (261.018)	-204.154** (79.448)
COVID	-0.190* (0.102)	-0.300* (0.169)	-	-
COVIDNEW	-	-	-34.233** (16.159)	-33.112* (18.448)
DIGITAL	0.136*** (0.041)	-	0.310** (0.120)	-
IB	-	1.250*** (0.388)	-	2.003** (0.800)
COVID*DIGITAL	0.0001* (0.0000)	-	-	-
COVID*IB	-	0.003** (0.001)	-	-
COVIDNEW*DIGITAL	-	-	0.014** (0.007)	-
COVIDNEW*IB	-	-	-	0.292* (0.163)
Marginal effect				
Minimum	-0.019* (0.009)	-0.039* (0.022)	-3.246** (1.513)	-4.308* (2.400)
Mean	-0.014* (0.007)	-0.020* (0.011)	-2.238** (1.037)	-2.156* (1.201)
Maximum	-0.005** (0.002)	-0.002** (0.001)	-0.629** (0.278)	-0.236* (0.133)

No. Subsector	24	24	24	24
Observation	264	264	264	264
Month dummy	Yes	Yes	Yes	Yes

Notes:

3. *, ** and *** denotes statistically significant at 10%, 5% and 1% level, respectively.
4. Values in parentheses are robust standard errors. Ln denotes the natural logarithm.

Endogeneity

This section addresses the issue of endogeneity, particularly reverse causality, in the model. The Fixed Effect (FE) estimator employed in the above analysis can address endogeneity due to omitted variable bias. However, the estimator cannot tackle the issue of reverse causality between the dependent and independent variables. From Eq. (3), the Covid-19 proxy is exogenous because it is unlikely that manufacturing sales performance would influence Covid-19 cases in the country. However, digital adoption is closely associated with manufacturing sales performance. Logically, manufacturers with higher sales performance tend to have greater capability to deploy more capital, such as digital technology, to facilitate the production process further. Hence, digital adoption is likely to be endogenous. Similarly, the interaction between Covid-19 and digital adoption (COVID*DIGITAL) is likely endogenous.

This study employs the Blundell and Bond (1998) proposed GMM estimator to mitigate the reverse causality issue. The estimator utilizes an internal instrument, namely the lag of the variable, to mitigate simultaneous bias. Given that the estimator requires a dynamic specification for the model, Eq. (3) is extended to include the lagged dependent variable in the model. However, the issue of serial correlation prevails when lag one of manufacturing sales growth rate is included. Accordingly, this study follows Ibrahim (2019) 's suggestion by extending the lagged dependent variable to lag 2 to render the autocorrelation problem.

In the practical implementation, the system GMM estimation is conducted based on the *xtabond2* routine proposed by Roodman (2009). Next, this study employs the two-step system GMM estimator to examine the mitigating effect of digitalization. The system GMM estimator consists of two variants: the one-step and two-step estimators. The two-step estimator is asymptotically more efficient than the one-step estimator because it uses optimal weighting matrices (Azman-Saini et al., 2010). However, its application to a sample with a small cross-section dimension may lead to biased standard errors. Hence, this study applied Windmeijer's finite sample correction to address the severe downward bias in the standard errors of the two-step system GMM estimates (Windmeijer, 2005). Next, this study followed Roodman (2009) 's suggestion of using the forward orthogonal deviations to remove the individual-specific effect. This method is more efficient than the first-difference transformation as it minimizes data loss.

Furthermore, the digital adoption (*DIGITAL*) and the associated interaction with Covid-19 (*COVID*DIGITAL*) are endogenous. Therefore these variables are instrumented with their lag values in the first-difference and level equation. However, this study will not use all the available lags as an instrument given a small cross-section unit (24 sub-sector). Using too many lags would result in an instrument proliferation problem and produce a biased estimate of the mitigating effect of digitalization. Hence, this study uses the collapse option to limit the number of instruments used in the estimator. Finally, the consistency of the GMM estimator depends on two specification tests, namely the Hansen J test of too many instruments and the autocorrelation test in the disturbances (Arellano and Bond, 1991). Failure to reject the null hypothesis for the Hansen J test indicates no instrument proliferation. For the autocorrelation test, one should not reject the absence of the second-order autocorrelation (AR(2)).

Table 8 shows the two-step system GMM estimation result. The marginal effect estimate shows the role of digitalization in mitigating the negative influence of the Covid-19 pandemic on manufacturing sales performance. The significant and consistent result reaffirms that the baseline finding is robust to the endogeneity of digital adoption. The marginal effect estimate shows that Covid-19 suppress manufacturing sales performance when digital adoption is low. However, the adverse impact diminishes with the rising level of digital adoption.

Post estimation diagnostic tests suggested that the estimation results of the two-step system GMM are valid. Failure to reject the Hansen J test indicated the validity of instruments used in the estimator. Similarly, failure to reject the null hypothesis of the Arellano-Bond statistic for error autocorrelation indicated the absence of error correlation. In addition, the number of instruments was less than the number of cross-section countries, indicating the absence of an instrument proliferation problem.

Table 8: Robustness check with two-step system GMM estimator

Covid-19 measure	Total Covid -19 cases per million population		New Covid -19 cases per million population	
	1	2	3	4
Constant	-1968.282***	-1017.884***	-3225.703***	-1266.847***
	(404.599)	(196.635)	(639.281)	(242.811)
$SALESMoM_{t-1}$	-0.286***	-0.323***	-0.383***	-0.377***
	(0.049)	(0.051)	(0.057)	(0.056)
$SALESMoM_{t-2}$	-0.363***	-0.405***	-0.408***	-0.392***
	(0.037)	(0.038)	(0.038)	(0.037)
COVID	-1.435***	-2.462***	-	-
	(0.289)	(0.499)		
COVIDNEW	-	-	-116.170***	-151.262***
			(22.820)	(28.010)
DIGITAL	0.889***	-	1.441***	-
	(0.182)		(0.286)	
IB	-	9.943***	-	12.040***
		(1.919)		(2.303)
COVID*DIGITAL	0.0006***	-	-	-
	(0.0001)			
COVID*IB	-	0.022***	-	-
		(0.004)		
COVIDNEW*DIGITAL	-	-	0.048***	-
			(0.009)	
COVIDNEW*IB	-	-	-	1.336***
				(0.247)
Marginal effect				
Minimum	-0.145***	-0.329***	-11.136***	-19.609***
	(0.029)	(0.066)	(2.189)	(3.635)
Mean	-0.103***	-0.170***	-7.718***	-9.772***
	(0.021)	(0.034)	(1.518)	(1.814)
Maximum	-0.036***	-0.027***	-2.263***	-0.996***
	(0.007)	(0.005)	(0.449)	(0.193)
No. Subsector	24	24	24	24
No. instrument	23	23	23	23
AR(2): p-value	0.423	0.364	0.625	0.510
Hansen test: p-value	0.125	0.133	0.123	0.127
Observation	216	216	216	216

Note:
1. *, ** and *** denotes statistically significant at 10%, 5% and 1% level, respectively.
2. Values in parentheses are robust standard errors. Ln denotes the natural logarithm.

VI. Conclusion and policy recommendation

In Malaysia, the outbreak of the Covid-19 pandemic brought conventional economic activities, such as manufacturing, to a standstill. The observation is reflected by the negative 2.6 percent year-on-year growth in the manufacturing sector in 2020. Likewise, manufacturing sales recorded a downturn of 2.2 per cent in the same year. Following the Movement Control Order (MCO) implementation, the manufacturing sector experienced the largest decline in sales in April 2020, with a negative 33 percent growth rate compared to the preceding month.

On the other hand, the pandemic accelerated the growth of digital adoption due to an abrupt increase in work from home, a surge in video-based content consumption, e-commerce and internet banking. The adoption of digital technology allows firms and businesses to operate remotely following a national lockdown, ensuring the continuation of economic activity and preserving the country's economic performance. Based on the above discussion, digitalization can be expected to play an important role in reducing the sales-deteriorating effect of the Covid-19 pandemic on the manufacturing sector. Accordingly, this study aims to provide an empirical investigation on whether digitalization mitigates the negative impact of Covid-19 on manufacturing sales performance in Malaysia.

Based on sectoral-level data from January 2020 to December 2020, the empirical result demonstrates that manufacturing sales performance is negatively associated with the Covid-19 pandemic. Digitalization plays an imperative role in mitigating the negative relationship. Specifically, the Covid-19 pandemic significantly and adversely impacts manufacturing sales performance if digitalization is low. However, the negative effect diminishes with the rising level of digitalization. Moreover, the mitigating effect of digitalization remains consistent in a series of robustness checks.

Based on the finding, this study offers three important policy recommendations to raise the degree of digital adoption in the Malaysian manufacturing sector. First, the Malaysian government could provide a tax incentive to encourage manufacturers to adopt digital technologies such as remote robots in the production process. Tax incentive plays an important role in providing additional cash flows to firms, thereby lessening their financial constraint and promoting greater investment. As a result, a tax credit would facilitate firms' investment behaviour and accelerate the pace of digitalization in the manufacturing sector. This practice has been widely adopted in developed countries to facilitate the degree of digitalization in the manufacturing sector. For instance, the Japanese and South Korean governments offer 15% (Kajimoto, 2019) and 6% (World Bank, 2021) tax credits to firms that invest in 5G infrastructure.

Second, the Malaysian government could provide public capital to support digital adoption among manufacturers. Public capital, such as providing a public grant programme, can address the financial constraint among small manufacturers, particularly Small and Medium Enterprises (SMEs). Generally, research and development activity is costly. Therefore financial support from the government is essential in helping small manufacturers to develop and adopt a digital solution in their production process. As a result, this would reduce the digital divide in the manufacturing sector, whereby all the manufacturers would have equal access and deploy digital technologies in their production process. The public grant programme is widely adopted in European countries. It is successful in helping SMEs to develop and adopt digital solutions. For instance, the European Innovation Council (EIC) offers grants worth 0.5 to 2.5 million euros to support SMEs that invest in 5G technologies (European Investment Bank, 2021).

Third, the Malaysian government should speed up the deployment of the 5G network in the country. Despite the introduction of Malaysia's Digital Economic Blueprint, Malaysia is relatively slow in deploying the 5G network compared to neighbouring countries such as Thailand. The term 5G indicates the 5th generation of mobile networks, which enables the application of big data, the Internet of Things (IoT) and Artificial Intelligence (AI) in various sectors of the economy.

In the manufacturing sector, the 5G network enables the application of remote robots, which enhances the production process's efficiency. Moreover, as indicated earlier, the remote robot allows manufacturing activity to operate remotely following a national lockdown, ensuring the continuation of manufacturing production. As a result, this 5G network helps manufacturers to sustain through the Covid-19 pandemic. Given the importance of 5G technology, the Malaysian government is urged to fasten the deployment of the 5G network in the country, thereby allowing manufacturers to adopt the 5G technology and sustain their business operations during the Covid-19 pandemic period.

Appendix 1: Sub-sector in the Malaysian manufacturing sector

No.	Sub-sector
1	Manufacture of food products
2	Manufacture of beverages
3	Manufacture of tobacco products
4	Manufacture of textiles
5	Manufacture of wearing apparel
6	Manufacture of leather and related products
7	Manufacture of wood and products of wood and cork
8	Manufacture of paper and paper products
9	Printing and reproduction of recorded media
10	Manufacture of furniture
11	Manufacture of cake and refined petroleum products
12	Manufacture of chemicals and chemical products
13	Manufacture of basic pharmaceutical products
14	Manufacture of rubber and plastic products
15	Manufacture of other non-metallic mineral products
16	Manufacture of basic metals
17	Manufacture of fabricated metal products
18	Manufacture of computers, electronics and optical
19	Manufacture of electrical equipment
20	Manufacture of machinery and equipment
21	Manufacture of motor vehicles, trailers and semi-trailers
22	Manufacture of other transport equipment
23	Other manufacturing
24	Repair and installation of machinery and equipment

Source: Department of Statistics Malaysia (DOSM)

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