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By Habibullah et al.

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Impact of Climate Change on (De)Industrialization in Malaysia: Robust Results

Muzafar Shah Habibullah*[a], Mohd Yusof Saari[b], Muhammad Daaniyall Abdul Rahman[c], and Muhammad Anas Nabil Al-Fattah Muhammad Yazid[b]

[a]*Putra Business School, Selangor, Malaysia*
[b]*Centre for Future Studies Berhad (The FUTURE), Malaysia*
[c]*School of Business and Economics, Universiti Putra Malaysia, Malaysia*

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The economic performance of the Malaysian economy has been consistently remarkable throughout the last five decades, considering the annual growth of the GDP. Malaysia gained independence in 1957 and had substantial progress over a span of 50 years, eventually reaching the classification of an upper middle-income developing nation in 1992. However, Malaysia has seen deindustrialization in recent years, despite its previous reputation for strong industrialization efforts. Deindustrialization is the process of manufacturing industries losing importance in the economy over time, usually accompanied by a transition towards services and other sectors. Regrettably, Malaysia's deindustrialization has been categorized as premature deindustrialization since the manufacturing sector's contribution to the country's GDP achieves its peak below the threshold level seen in industrialized nations. The objective of this study is to analyze the influence of climate change on the deindustrialization process in Malaysia between 1970 and 2020. The climatic change variables were denoted by temperature and precipitation, whereas deindustrialization was measured by the ratio of manufacturing output to total gross domestic product. We used five estimators to examine the impact of climate change on deindustrialization, namely the Ordinary Least Square (OLS) technique with robust standard error, Robust regression with

*Corresponding author: muzafar@putrabs.edu.my

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M-estimator, Fully-modified OLS, Dynamic OLS, and Canonical Cointegrating Regression approaches. The study incorporates control factors such as real income level, crude oil price, real interest rate, and financial development. Overall, our results suggests that extreme weather events, such as extreme heat and heavy rainfall, accelerate the deindustrialization process in Malaysia. Conversely, an increase in the price of crude oil and the real interest rate has an adverse effect on industrialization. On the other hand, a rise in both level of income and financial development directly enhances industrialization as measured by the share of manufacturing output to gross domestic product.

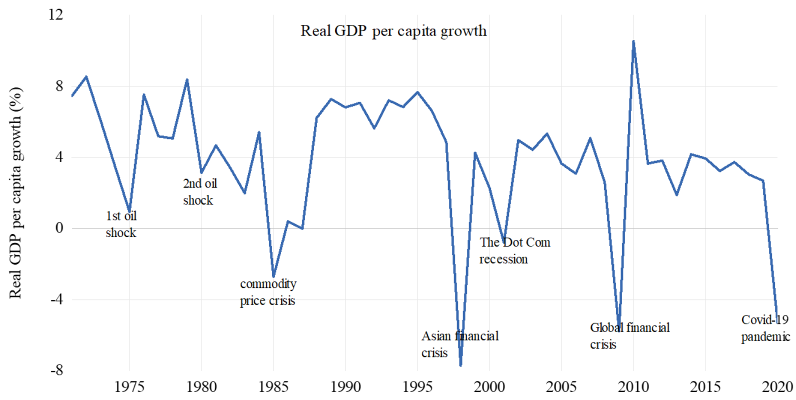
keywords: deindustrialization, climate change, temperature, precipitation, Malaysia.

1 Introduction

1.1 Malaysia's 50 Years Economic Performance

Malaysia has shown a tremendous economic performance during the previous five decades. Since gaining independence in 1957, Malaysia has seen significant development and achieved the status of an upper middle-income developing country by 1992. Malaysia's gross domestic product (GDP) per capita was RM6,775 (in 2020 constant prices) in 1970. By 2020, Malaysia's GDP per capita had increased to RM43,378. Figure 1 illustrates a consistent upward trajectory of the GDP per capita from 1970 to 2020. Nevertheless, there were setbacks in many years, notably during the first oil shock of 1975, the commodity price crisis in 1985–86, the Asian financial crisis in 1997, the worldwide financial crisis of 2008–09, and the unprecedented Covid-19 pandemic in 2020. Figure 1 illustrates the fluctuating nature of Malaysia's economic development in the 1970s, mostly influenced by changes in commodity prices. However, Malaysia also saw more consistent economic growth in the early 1990s, 2000s, and the decade leading up to the Covid-19 pandemic. The export-oriented industrialization programme implemented from 1970 to 1980, as shown by Tan (2014), successfully contributed to Malaysia's economic development, with an average growth rate of 7.4% during the period of 1971–1973 and 6.6% during the period of 1976–1979. This era had a significant increase in economic activity, driven by robust commodity prices. In spite of this notable expansion, Malaysia experienced the first oil crisis in 1974–75 and the subsequent oil crisis in 1980.

During the 1980s and 1990s, the industrial policy, known as the Industrial Master Plan 1 (1986–95) and Industrial Master Plan 2 (1996–2000), focused on promoting heavy industries, privatisation, foreign control of advanced technology, and a thriving export sector centred around high-tech electronics and electrical components. This strategy resulted in an impressive average economic growth rate of 6.8% between 1988 and 1996. In the 1980s and 1990s, Malaysia had two economic crises: the commodities price crisis from 1985 to 1986 and the Asian financial crisis in 1997. Following its recovery from the 1997 Asian financial crisis, Malaysia saw a consistent and steady average growth rate from 2002 to 2007. Unfortunately, Malaysia encountered another financial crisis



Source: Calculated using APO Productivity Database 2021.

Figure 1: Growth in real GDP per capita in Malaysia, 1970-2020

during the period of 2008–09. In 2009, Malaysia had a decline in economic growth of 5.8% due to the global financial crisis. However, this was less severe than the negative growth of 7.7% during the 1997 Asian financial crisis. However, Malaysia faces yet another problem in 2020. The Covid-19 pandemic has led to a decline of 5.3% in economic growth in 2020. Between 2011 and 2019, the world economy saw an average growth rate of 3.4% after the global financial crisis and before the Covid-19 pandemic. The decline in Malaysia's economic growth rate after 2000 may be attributed to the process of deindustrialization that the country underwent. Additionally, the expansion of China's export-oriented manufacturing sector has intensified competition for Malaysia. Since 2000, the manufacturing sector's proportion of total gross domestic product and employment in manufacturing to total employment has been decreasing (Rasiah, 2011; Rasiah et al., 2015).

The Malaysia's manufacturing sector is diverse and includes several key components. The electrical and electronics (E&E) industry is the largest, accounting for approximately 35.6% of total manufacturing output, followed by petroleum products, chemicals, rubber, and plastics (Malaysian Investment Development Authority, 2023). Other important subsectors include machinery and equipment, food and beverages, and transport equipment. These industries contribute significantly to Malaysia's export earnings and employment. While E&E is more insulated from climate impacts, sectors such as food processing and rubber manufacturing are sensitive to climate variability, particularly changes in agricultural input supply chains (World Bank, 2020).

1.2 (De)Industrialization in Malaysia

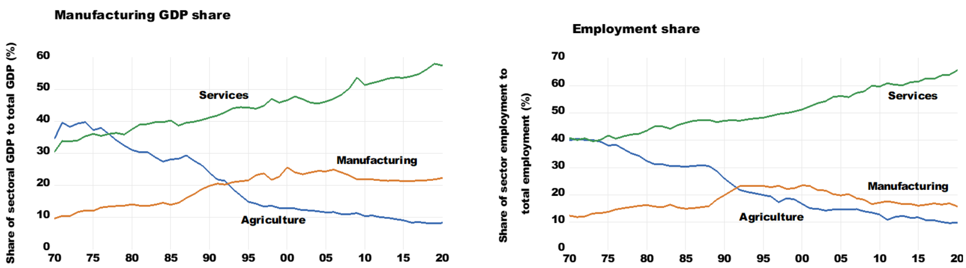
Industrialization has been widely acknowledged as the primary pathway by which countries may achieve sustainable long-term economic development and improve their standard of living. Industrialization entails the transition from an economy mostly reliant on traditional agriculture to one that is predominantly centred on manufacturing. According to Kaldor (1963) and Kuznets (1971), throughout the first phases of economic growth, the agricultural sector served as the primary contributor to both production and employment. As the economy advances and income rises, there is a transition of production and employment from the farm sector to the manufacturing sector, which becomes the next catalyst for economic expansion. The manufacturing sector is widely recognised as a highly innovative and technologically advanced industry. The industrial sector has the capacity to achieve higher levels of capital accumulation, economies of scale, and technical advancement in comparison to the agrarian sector. Moreover, the expansion of the manufacturing sector accelerates the pace of technological advancement in the entire economy, partly due to the utilisation of excess labour and the generation and spread of innovations in specific industries through the linkage effect (Kaldor, 1967; Marconi et al., 2016). Deindustrialization refers to the transition in economic development from the manufacturing sector to the services sector, indicating a change in consumer demand from manufacturing to services.

Deindustrialization is seen as an unavoidable result of economic development. As income per person increases, manufacturing becomes more important than agriculture. However, there is a point where manufacturing starts to decline and the services sector becomes more important (Tregenna, 2016). At the specific point when income per person reaches a certain level, the services sector begins to employ more people at the expense of the manufacturing sector. This is because improvements in productivity enable manufacturing activities to operate with fewer workers, while the services sector can accommodate the surplus labour from the manufacturing sector (Caceres, 2017). Rowthorn and Ramaswamy (1997), Palma (2014), and Rodrik (2016) have provided definitions for the word "deindustrialization" as the reduction in the proportion of employment (compared to total employment) and/or the proportion of GDP (compared to total GDP) contributed by the manufacturing sector. Thus, (de)industrialization poses both challenges and opportunities for Malaysia. On the negative side, it may lead to employment displacement, loss of manufacturing-related skills, reduced innovation capacity, and weakening of industrial linkages (Tregenna, 2016). These consequences can slow productivity growth and increase vulnerability to external shocks. However, transitioning towards a service-oriented economy can also bring merits, including diversification of economic activities, expansion of high-value services, and growth in knowledge-based sectors (Rodrik, 2016). Services, particularly financial, digital, and tourism sectors, offer potential for innovation and export revenues. It is crucial to manage the transition carefully to avoid premature deindustrialization and to ensure inclusive, sustainable economic development.

Figure 2 illustrates the changes in the proportion of Malaysia's GDP allocated to the agricultural, manufacturing, and services sectors from 1970 to 2020. According to Figure 2, the agricultural sector had a bigger percentage in the Gross Domestic Product (GDP) compared to the industrial sector in the early 1970s. It contributed to over 40% of the total GDP. However, it saw a significant reduction until it reached 1995. Subsequently, it steadily decreased to below 10% of GDP between 2013 and 2020. The contribution of the manufacturing sector to the GDP shown a consistent rise, starting at about 10%

of the GDP in the early 1970s and reaching its highest point in 2000, with a share of 26% in the GDP. Subsequently, the percentage of manufacturing in the GDP began to decline until 2009, stabilising at around 22% of the GDP. In the year 2000, Malaysia had a per capita income of approximately US$6,500 (constant 2015=100, upper middle-income group), which was lower than the peak income level of industrialised nations during deindustrialization, which was around US$10,000 in current price (Dasgupta and Singh, 2007). Additionally, Malaysia had a per capita income of around US$9,500 in 1995 purchasing power parity (Rowthorn and Coutts, 2004). Conversely, the services sector's contribution to the Gross Domestic Product (GDP) has seen a significant rise, growing from around 34% in the early 1970s to 58% of GDP in 2020. The data indicates that the proportion of the agricultural and manufacturing sectors decreased from 1971-1980 to 2011-2020, while the proportion of the service sector in the Gross Domestic Product (GDP) increased with time.

The proportion of employment in the agricultural, manufacturing, and services sectors relative to overall employment is displayed in Figure 2. A nearly identical pattern can be easily noticed, where the proportion of employment in the manufacturing sector is the exact opposite of the proportion of employment in the agricultural sector. Commencing with a 40% portion of employment in the agricultural industry, it steadily diminishes over time until it reaches a 10% share in the year 2020. Conversely, the proportion of jobs in the manufacturing industry has consistently risen from approximately 12% of total employment in the early 1970s to a peak of around 24% in 2000. Subsequently, there has been a gradual decline in the share of manufacturing employment, reaching 16% of total employment by 2020. Nevertheless, the proportion of employment in the services industry has consistently risen, escalating from around 41% in 1970 to 66% in 2020.



Source: Calculated using APO Productivity Database 2021.

Figure 2: Trends in agriculture, manufacturing and services GDP share to total GDP, and employment share to total employment in Malaysia, 1970-2020

The manufacturing output proportion to total output and employment share to total employment both indicate the deindustrialization trend in Malaysia since 2000. These scenarios align with the conclusions reached by Rasiah (2011) and Rasiah et al. (2015). Figure 2 illustrates that Malaysia underwent premature deindustrialization due to two factors. Firstly, Malaysia's proportion of manufacturing GDP in relation to total GDP reached its highest point at a per capita income lower than that of developed nations. Secondly, the decline in employment share was less significant than the decline in GDP share. The fact refers to the occurrence of early deindustrialization in Malaysia, as discussed by Asyraf et al. (2019).

The purpose of this study is to examine the impact of climate change on Malaysia's (de)industrialization from 1970 to 2020. Studies have acknowledged that climate change may adversely impact the economy via several channels, including property and infrastructure damage, trade and supply chain disruption, decreased labour productivity and human health, and heightened energy consumption and expenditures. These consequences have the potential to hinder the development of industrialization in any country. In this study, we are examining temperature and rainfall as indicators of climate change. Additional factors included in the present study as control variables include income per capita, oil price, interest rate, and financial development.

2 Climate Change and (De)Industrialisation

Climate is the long-term average of weather patterns in a particular area, usually spanning 30 years or more, and it involves the long-term alteration of temperature and usual weather patterns in any region (Baede et al., 2001). The expected values of these meteorological elements over a specific location and time period, plays a crucial role in determining the distribution of vegetation, soil types, and even the types of clothing and housing that people have developed over time (Hartmann, 2016). The surface climate of the Earth is highly varied, ranging from the scorching heat of the tropics to the frigid cold of the polar regions, and from the arid drought of a desert to the lush moisture of a rain forest (Hartmann, 2016; Demuth et al., 2011). Weather, on the other hand, refers to the temporary changes in atmospheric conditions which includes factors like as temperature, rainfall, wind, and humidity that individuals encounter on a regular basis while going outside. The weather, a constant and ever-changing presence in our lives, exerts a significant influence on our daily experiences, shaping our routines, activities, and overall well-being. From the moment we step outside, we are confronted with the temporary conditions of the atmosphere, such as temperature, rainfall, wind, and humidity, which can profoundly impact our day-to-day lives.

While the climate of a region is generally stable, the weather can be highly unpredictable and subject to sudden changes, often with significant consequences. A general rain, a frosty night, or a summer drought can affect not only, for example, a single plant but also thousands of other plants in a field, a county, or even several states (Moss, 2015). This is because the local climate or environment, although controlled in general by the climate of the region, may differ markedly from another local climate just a short distance away.

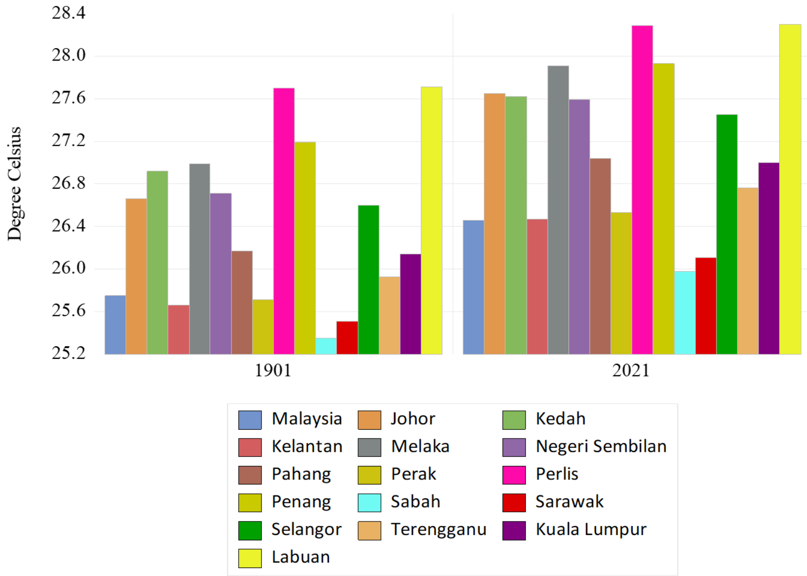
Climate change can be the result of a mix of both natural and human-induced forces. The natural factors that contribute to long-term climatic variations include changes in solar activity, volcanic eruptions, fluctuations in Earth's orbit, axial tilt, orbital shape, continental drift, atmospheric composition, and interactions between the ocean and atmosphere (Baede et al., 2001; Hansen, 2007). The solar radiation's thermal energy transfer to the atmosphere and Earth's surface is crucial in determining the characteristics of both climate and weather (Zhong, 2022). These natural elements contribute to long-term climatic variations, exemplified by events like as ice ages and interglacial periods, which can take place over extended periods of time, ranging from tens of thousands to hundreds of thousands of years (Baede et al., 2001; Hansen, 2007).

Climate change has emerged as a formidable threat, capable of exacerbating the frequency, intensity, and duration of various natural calamities (Cutter et al., 2013). These events, ranging from floods and storms to droughts and wildfires, are deeply intertwined with the disruptions in the water cycle, atmospheric conditions, and sea levels - all of which are profoundly influenced by the changing climate (Trenberth, 2018; López et al., 2020; Webster et al., 2009). The repercussions of climate change extend far beyond environmental degradation, with a cascade of impacts that threaten human health and well-being globally. The severe droughts, water shortages, and increased fire hazards associated with climate change directly undermine access to essential resources, leading to decreased agricultural production and lack of access to food. These conditions heighten the vulnerability of populations to contagious illnesses, respiratory ailments, and mental health disorders (Khanjani, 2016).

The warming and deoxygenation of oceans, as well as the melting of polar ice, contribute to rising sea levels and devastating storms that displace communities and destroy critical infrastructure (Martin et al., 2023; Khanjani, 2016; Short et al., 2017). These climate-driven natural catastrophes also result in the loss of biodiversity, which can further disrupt ecological balances and enable the spread of parasitic diseases. The overall health effects of climate change are likely to be extremely negative, as it impacts the social and environmental determinants of health, such as access to clean water, food, and adequate shelter (Khanjani, 2016). The poorest and most vulnerable populations are expected to bear the brunt of these consequences, due to insufficient health systems and resources to adapt to such dramatic environmental changes (Kumaresan and Sathiakumar, 2010).

The climatic changes in Malaysia can be observed by examining the changes of both temperature and precipitation over 120 years. The mean temperature in Malaysia has had a 2.8% increase, going from 25.75 degrees Celsius in 1901 to 26.46 degrees Celsius in 2021. Simultaneously, the mean yearly rainfall has seen a notable increase of 21.5%, rising from 2712.83 mm in 1901 to 3297.34 mm in 2021. According to Figure 3, in 1901, only two states, Perlis and Labuan, had a mean temperature exceeding 27.2 degrees Celsius. However, as of 2021, more states have seen mean temperatures exceeding 27.2 degrees Celsius. The states included in this list are Johor, Kedah, Melaka, Negri Sembilan, Penang, and Selangor.

However, according to Figure 4 and Table 1, the states of Johor, Melaka, and Negeri Sembilan have had a rainfall rise of over 50% in the previous 120 years. Pahang, Selangor, and Kuala Lumpur had a rainfall surge of over 40% within the same time frame. The occurrence and severity of floods in Malaysia, along with other natural hazards such as landslides, droughts, heat waves, and storms, will be exacerbated by climate



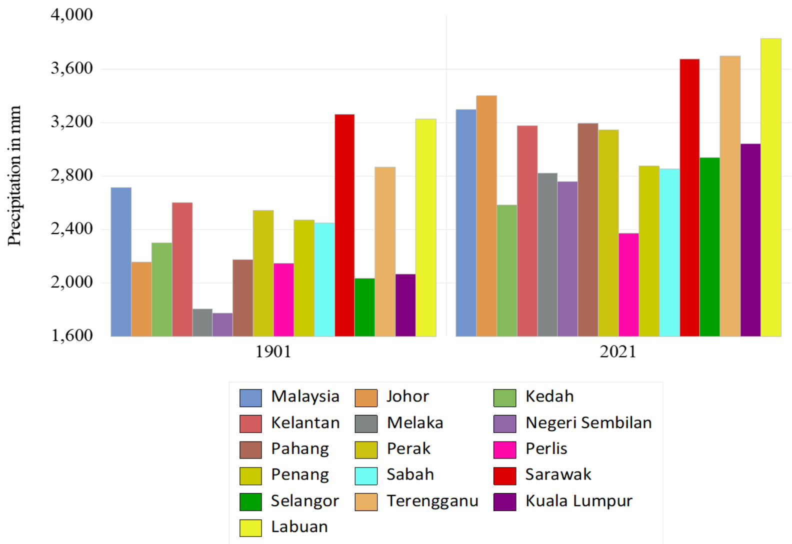
Source: World Bank's Climate Change Knowledge Portal

Figure 3: Changes in mean temperature (Celsius) between 1901 and 2021

change. This will heighten the susceptibility and visibility of the people, particularly the impoverished and marginalised, who possess little skills and resources to manage and recuperate. The flood occurrences seen in these states during the previous two decades clearly demonstrate the changes in precipitation patterns.

Climate change, particularly changes in temperature, will have a direct impact on the productivity and long-term viability of important sectors including agriculture, forestry, fisheries, and tourism. These industries heavily rely on natural resources and ecosystem services. For instance, changes in temperature, precipitation, pests, and illnesses would impact the productivity of crops, livestock production, and the overall security of food supply. Fluctuations in ocean temperature, acidity, salinity, and currents will have an impact on the abundance and distribution of fish populations, as well as the health and survival of coral reefs and coastal ecosystems. Tourism demand, supply, and income will be impacted by fluctuations in weather patterns, seasons, natural attractions, and cultural heritage.

Studies have shown that temperature has a substantial influence on labour productivity, and as a result, on the production and economic advancement. Studies conducted by Zhang et al. (2018) and Zivin et al. (2018) have shown that fluctuations in temperature over a short period of time might impact the total factor productivity in both the agricultural and industrial sectors. Additionally, these temperature variations can also influence the distribution of work hours and potentially lead to a rise in mental health issues. Hotter temperatures may exacerbate individuals' irritability, hostility, and aggression, hence increasing the likelihood of engaging in violent and impulsive activities.



Source: World Bank's Climate Change Knowledge Portal

Figure 4: Changes in rainfall (mm) between 1901 and 2021

Temperature variations may impact economic development via the escalation of crime rates, heatstroke incidents, wildfires, internal conflicts, and frequent changes in political regimes (Burke et al., 2009). Escalating temperatures may potentially result in societal upheaval caused by starvation resulting from prolonged drought (Caruso et al., 2016). Severe temperature may initiate population migrations and result in substantial migration, which can in turn raise the occurrence of conflict in the arrival of refugees and impact social stability (Hsiang et al., 2013). In addition, extreme temperatures might immediately result in decreased agricultural production and cause rural households with lower incomes to relocate to regions with more favourable climates, resulting in shifts in the regional workforce (Marchiori et al., 2012).

The impact of temperature shocks may transmit from the agriculture sector, and further downstream to industrial manufacturing sector (Roberts and Schlenker, 2012). Furthermore, increasing temperatures might impact the operations of several industrial sectors, diminishing the efficiency of air conditioning systems and perhaps causing workers to be absent (Deschenes and Moretti, 2009). Therefore, any variations in temperature will have a direct impact on agricultural production and an indirect impact on industrial and service sectors. Temperature shocks have the potential to disrupt the spatial balance of the global economic system, disrupt supply chains, or redistribute labour, which may have an influence on international commerce and eventually affect economic development. Temperature shocks may prompt nations to implement import methods to counteract the impact of temperature on domestic businesses and agriculture, while also decreasing the export of regions vulnerable to temperature shocks. Hence, if the temperature beyond a certain threshold, whether it is too high or excessively low, it

Table 1: Comparison of Temperature and Rainfall by States (1901 vs 2021)

	Temperature (Celsius)			Rainfall (mm)		
States	1901	2021	growth (%)	1901	2021	growth (%)
Malaysia	25.75	26.46	2.8	2712.83	3297.34	21.5
Johor	26.66	27.65	3.7	2154.10	3399.34	57.8
Kedah	26.92	27.62	2.6	2297.20	2582.02	12.4
Kelantan	25.66	26.47	3.2	2598.64	3177.23	22.3
Melaka	26.99	27.91	3.4	1803.32	2820.83	56.4
Negeri Sembilan	26.71	27.59	3.3	1774.42	2757.61	55.4
Pahang	26.17	27.04	3.3	2174.44	3193.84	46.9
Perak	25.71	26.53	3.2	2543.72	3143.72	23.6
Perlis	27.70	28.29	2.1	2146.14	2369.75	10.4
Pinang	27.19	27.93	2.7	2470.17	2873.66	16.3
Sabah	25.35	25.98	2.5	2448.21	2853.32	16.5
Sarawak	25.51	26.11	2.4	3261.22	3675.05	12.7
Selangor	26.60	27.45	3.2	2034.69	2937.00	44.3
Terengganu	25.93	26.76	3.2	2867.67	3698.97	29.0
Kuala Lumpur	26.14	27.00	3.3	2065.30	3042.40	47.3
Labuan	27.71	28.30	2.1	3225.90	3829.60	18.7

Source: World Bank's Climate Change Knowledge Portal

will cause a decline in both labour productivity and labour supply capacity, ultimately leading in a drop in output.

However, there is evidence indicating that climate change has an impact on precipitation patterns (Dore, 2005). This, in turn, might possibly influence economic development due to the unpredictability in rainfall (Ali, 2012). Severe meteorological conditions, such as typhoons and hurricanes, result in significant economic losses for families. These disasters damage infrastructure, durable assets, buildings, and factories in the aftermath of storms (Anttila-Hughes and Hsiang, 2013). Leiter et al. (2009) provides evidence that enterprises located in flood-affected areas see a significant increase in total assets and employment in the short-term, relative to firms in regions untouched by floods. Additionally, they discover that a portion of the capital is more resistant to calamities. Firms that have a higher proportion of intangible assets tend to have a beneficial impact. Leiter et al. (2009) note that during floods, firms with a small proportion of tangible assets undergo a significant rise in the accumulation of physical capital. Consequently, the detrimental impact on a firm's productivity decreases as the proportion of intangible assets increases.

Tobin and Montz (1997) suggest that inhabitants of Linda and Olivehurst in California, who have been affected by catastrophic floods, see enduring effects on property values. After floods, various properties suffer varying degrees of damage, necessitating the owners to repaint, replace all appliances, and replace carpeting. Therefore, it is necessary to raise the prices of houses. According to Gruntfest (1995), the persistent disturbance of people's means of making a living and the deprivation of land and other possessions would heighten their susceptibility to floods and poverty in the long run. Becken and Wilson (2013) found that excessive rainfall and drought had an impact on the financial success and level of interest in the tourist industry in New Zealand.

In their study, Sangkhaphan and Shu (2020) discovered that the primary effects of the weather in Thailand were manifested via rainfall and a decrease in Gross Regional and Provincial Product (GPP) at the countrywide scale. At the sector level, the findings indicated that rainfall had a noteworthy adverse effect on the agricultural and service sectors, but its effect on the industrial sector was favourable but not statistically significant. Nevertheless, precipitation continues to be crucial in impoverished areas, despite its potential harm to certain subsectors within those regions.

In Malaysia, the effects of climate change can differ, but it can affect indirectly or directly on the different sectors or industries. For example, while the E&E and chemical sectors are less directly climate-sensitive compared to agriculture, climate change can affect these industries indirectly through multiple systemic channels, including energy disruptions, supply chain shocks, labour productivity impacts, and infrastructure resilience (Burke et al., 2015). For instance, higher temperatures can reduce labour productivity across sectors by increasing heat stress, impairing cognitive performance, and raising occupational health risks, particularly in manufacturing and logistics operations (Zivin and Neidell, 2014; Kjellstrom et al., 2016). Moreover, floods and extreme weather events — increasingly frequent under climate change — can damage logistics networks, disrupt port operations, hinder transportation of intermediate goods, and trigger temporary or long-lasting supply chain failures (Sadoff et al., 2015; Ebi and Bowen, 2016).

Furthermore, critical industrial zones, including free trade zones and industrial parks, are often located near coasts or river basins in Malaysia, making them particularly vulnerable to sea-level rise, storm surges, and inland flooding (Dasgupta et al., 2009). Infrastructure damage, including roads, electricity grids, and communication networks, further amplifies disruptions in manufacturing production, even in sectors without direct climate exposure (Hallegatte et al., 2019). In addition, climate-induced energy insecurity, such as hydroelectricity shortfalls due to altered rainfall patterns or heatwave-driven electricity demand spikes, can impose operational constraints on energy-intensive industries like E&E and chemicals (International Energy Agency, 2021).

Floods in Malaysia are a recurring occurrence that result in suffering, property destruction, and loss of life (Chan, 1997; Chan and Parker, 1996). Shah et al. (2017) reported that Malaysia has seen a sequence of floods caused by severe weather since 1920. The monsoon flood that occurred between December 2014 and January 2015 is considered to be one of the most devastating floods to hit Malaysia. The floods that occurred in December 2006 and January 2007 are widely regarded as the most destructive floods in the history of Malaysia. In 2021, Malaysia incurred losses due to flood amounting to RM6,112 million of which losses in infrastructure takes up 32.7% followed by living quarters (26.5%), vehicles (16.1%), manufacturing sector (14.6%), business premises (8.6%) and agriculture (1.5%) (Department of Statistics Malaysia, 2022).

Thus, it is justified to include climate change variables in assessing deindustrialization, as they capture broader systemic risks and sectoral interdependencies, extending beyond direct agricultural sensitivities to encompass cross-sector spillovers, macroeconomic stability, and industrial resilience (Stern, 2007; Diffenbaugh and Burke, 2019). Neglecting these indirect pathways would underestimate the full economic impacts of climate change on Malaysia's manufacturing performance.

3 Methodology

3.1 The Estimating Model

In order to empirically assess the influence of climate change on the process of (de)industrialization in Malaysia, we use the model presented in the works of Farajzadeh et al. (2023), Sangkhaphan and Shu (2020), Rowthorn and Ramaswamy (1997), Skuflic and Druzic (2016), and Araujo et al. (2021). In this model, we used temperature and rainfall as indicators of climate change,

$$\begin{aligned} mfgy_t = {} & \alpha_0 + \alpha_1 temp_t + \alpha_2 temp_t^2 + \alpha_3 rain_t \\ & + \alpha_4 rgdppc_t + \alpha_5 oilprice_t + \alpha_6 int_t + \alpha_7 findev_t + \mu_t \end{aligned} \tag{1}$$

All variables in the equation are expressed in logarithmic form. The variable $mfgy_t$ represents the ratio of the manufacturing sector's gross domestic product (GDP) to the national GDP, which serves as a measure of (de)industrialization. The variables $temp_t$ and $temp_t^2$ represent temperature and its square, respectively. The connection between the manufacturing-output ratio and temperature is anticipated to be nonlinear, with α_1 being more than zero and α_2 being less than zero. This implies that the relationship follows an inverted U-shaped curve. In this study, we use the maximum temperature as a proxy for measuring temperature. $rain_t$ refers to the amount of rainfall, which is another indicator used to assess climatic changes in this study. The anticipated effect of rainfall on $mfgy_t$ is expected to be negative, specifically $\alpha_3 < 0$.

The control variables consist of the following: $rgdppc_t$ represents real GDP per capita; $oilprice_t$ represents the price of crude oil (specifically Brent crude oil); int_t represents the real interest rate (real lending rate); and $findev_t$ represents financial development, which is measured as the ratio of credit to the private sector to GDP. The expected impacts of $rgdppc_t$, $oilprice_t$, int_t and $findev_t$ are as follows: $\alpha_4 > 0$, $\alpha_5 < 0$, $\alpha_6 < 0$ and $\alpha_7 > 0$, respectively. The error term is assumed as usual, $\mu_t \sim NID(0, \sigma)$.

Generally, a higher real GDP per capita has a positive effect on manufacturing production, as measured by the ratio to GDP. This implies that an increase in income, which serves as a proxy for increased demand, would lead to a rise in manufacturing output.

Moreover, a favourable consequence of financial development suggests that a higher degree of financial development would augment the level of manufacturing production as a result of the accessibility of loans and advances in the financial sector. Conversely, the negative impact of rising oil prices and increasing interest rates would raise production costs, leading the business to decrease output.

Real GDP Per Capita: Economic development, often proxied by real GDP per capita, plays a central role in shaping a country's industrial trajectory. According to Kuznets (1971), as incomes rise, economies typically shift from agriculture to manufacturing, marking a phase of industrialization. However, when economies reach middle- or high-income levels, a gradual transition towards services becomes evident – a phenomenon known as deindustrialization (Rowthorn and Ramaswamy, 1997). In Malaysia, the industrialization boom of the 1980s-1990s coincided with rapid income growth, facilitated by export-oriented manufacturing (Rasiah, 2011). Yet, recent trends suggest premature deindustrialization, where manufacturing GDP and employment shares decline before reaching high-income thresholds (Rodrik, 2016). This is partly attributed to rising incomes shifting demand towards services and limiting manufacturing's role as an employment generator (Dasgupta and Singh, 2007). Therefore, real GDP per capita is not only an indicator of development stage but also a structural driver influencing Malaysia's sectoral composition.

Moreover, research highlights that as real GDP per capita grows, consumer preferences tend to shift towards services, luxury goods, and higher-quality products, altering the demand structure of the economy (Tregenna, 2016). In Malaysia, this shift is visible in the growing service sectors, including finance, education, healthcare, and tourism, which now contribute a larger share to GDP. However, without parallel efforts to upgrade manufacturing (e.g., via automation, innovation, and global value chain integration), income-led demand shifts may accelerate deindustrialization and reduce Malaysia's long-term competitiveness (Rasiah, 2011). Therefore, policymakers must recognize GDP growth as both an opportunity and a challenge for sustaining a balanced economic structure.

Crude Oil Price: Oil prices significantly influence industrial dynamics, particularly in resource-dependent economies like Malaysia. High crude oil prices increase production costs through energy price pass-through, affecting manufacturing profitability and competitiveness (Hamilton, 2009). Sectors that are energy-intensive, such as cement, steel, and petrochemicals, face direct cost escalations, while export-oriented sectors experience reduced global demand due to cost-push inflation (Farajzadeh et al., 2023). Moreover, oil price volatility can create investment uncertainty, deterring long-term industrial investment (Balcilar et al., 2016). In Malaysia, a net oil exporter until recently, high oil prices historically benefited government revenues but imposed higher input costs on manufacturers, creating a complex interaction between resource wealth and industrial structure (Abdullah and Said, 2017). Therefore, crude oil prices act as both a macroeconomic and sector-specific determinant of (de)industrialization pathways.

Additionally, the dual role of Malaysia as both an energy producer and consumer make the relationship between oil prices and industrialization particularly nuanced. While higher oil prices can bolster national fiscal revenues, these gains often translate into resource dependence, sometimes leading to the "Dutch disease" – where resource booms cause currency appreciation, weakening the competitiveness of non-resource manufacturing exports (Palma, 2014). For Malaysia, this has raised concerns over the hollowing-out of certain manufacturing subsectors that are less shielded from global energy price cycles. As such, managing the macroeconomic impacts of oil price fluctuations becomes critical to safeguarding Malaysia's industrial base.

Interest Rate: The interest rate, particularly the real lending rate, is a critical macroeconomic policy tool that affects industrial activity through capital cost channels. Bernanke and Gertler (1995) emphasize that higher real interest rates increase borrowing costs, dampening firm investment, especially in capital-intensive manufacturing sectors. In Malaysia, studies have shown that tight monetary policy episodes – marked by elevated interest rates – reduce credit availability to firms, limiting industrial expansion (Tang, 2006). Conversely, lower interest rates facilitate investment and working capital financing, enabling firms to upgrade technologies, expand production, and improve competitiveness. Importantly, the manufacturing sector's sensitivity to interest rate fluctuations may be higher than that of services, given its reliance on fixed capital and long-term investment planning (Levine, 2005).

Furthermore, manufacturing firms in emerging economies like Malaysia often face additional barriers, such as limited internal financing capacity and collateral constraints, making them more dependent on external credit (Beck et al., 2005). As a result, even modest increases in real interest rates can disproportionately affect small and medium-sized manufacturers compared to large conglomerates. This dynamic has implications for industrial structure, potentially accelerating market concentration, reducing innovation capacity among SMEs, and weakening the diversity of the industrial base. Therefore, maintaining an interest rate environment supportive of inclusive industrial development is crucial for Malaysia's long-term economic health.

Financial Development: Financial development, often measured by credit to the private sector as a percentage of GDP, enhances the capacity of firms to access funds for investment, innovation, and productivity improvements (Levine, 2005). A robust financial system reduces information asymmetries, lowers transaction costs, and enables efficient capital allocation, all of which are essential for sustaining industrial growth (Rajan and Zingales, 1998). In the Malaysian context, the expansion of financial services since the 1990s has supported industrial upgrading, particularly in export-oriented industries (Rasiah, 2011). However, unequal access to finance – where large, established firms benefit more than SMEs – can exacerbate industrial concentration and limit broad-based industrialization (Beck et al., 2005). Thus, financial development acts as both an enabler and moderator of industrial dynamics, influencing the pace and inclusiveness of structural transformation.

In addition, the composition and quality of financial intermediation matter significantly for industrial outcomes. Evidence suggests that countries with bank-based systems may favour established firms and traditional industries, while market-based systems (e.g., equity markets, venture capital) tend to channel funds toward innovative and emerging sectors (Levine, 2005; Rajan and Zingales, 1998). In Malaysia, ongoing efforts to diversify financial instruments – including the growth of Islamic finance, fintech, and SME credit facilities – are seen as potential levers to stimulate industrial dynamism and resilience. By improving financial inclusivity and tailoring financing products to industrial needs, Malaysia can better harness financial development to mitigate deindustrialization risks.

In summary, temperature and rainfall are included as key proxies for climate-induced productivity shocks, reflecting both direct impacts on agricultural and industrial productivity and indirect effects through labour supply, health, and infrastructure disruptions (Burke et al., 2015; Dell et al., 2012; Zivin and Neidell, 2014). Empirical studies have shown that even modest increases in temperature can lower total factor productivity in both developed and developing countries, making it an essential factor in modelling economic performance and sectoral dynamics (Hsiang, 2010). Rainfall variability similarly affects economic outcomes by influencing agricultural outputs, hydroelectric generation, and disaster risks, which can spill over into manufacturing and services (Sadoff et al., 2015; Damania, 2006).

Income per capita (real GDP per capita) is included as a proxy for demand-side factors, reflecting the structural transition of economies from agriculture to manufacturing and then to services as incomes rise (Kuznets, 1971; Rowthorn and Ramaswamy, 1997). It also captures market size, consumer demand, and potential for industrial upgrading (Felipe et al., 2014). Crude oil price is selected as a global cost determinant, as oil is a fundamental input for energy and transportation, influencing production costs across sectors (Hamilton, 2009; Farajzadeh et al., 2023). In energy-intensive industries, oil price volatility can disrupt investment plans, profitability, and competitiveness, especially in open economies like Malaysia.

The real interest rate is included to capture the monetary and credit environment. Higher real interest rates increase borrowing costs, deter capital investment, and constrain firm-level expansion, particularly in capital-intensive industries such as manufacturing (Bernanke and Gertler, 1995; Aghion et al., 2009). In contrast, lower interest rates can stimulate industrial growth by easing financing conditions. Finally, financial development, measured by credit to the private sector, reflects the economy's capacity to allocate resources efficiently, support innovation, and enable firm growth (Levine, 2005; Rajan and Zingales, 1998). Countries with deeper financial systems are better positioned to finance industrial transformation, support SMEs, and cushion sectors against external shocks. Collectively, these independent variables are widely used in macroeconomic and climate-economy literature to explain structural change, sectoral shifts, and long-run growth trajectories.

3.2 Sources of Data

This study utilises yearly time series data from Malaysia spanning the years 1970 to 2020, resulting in a total of 51 observations. Table 2 presents the data sources and measurement details for each variable used in the investigation. The dependent variable used to assess (de)industrialization in Malaysia is the ratio of manufacturing GDP to total national GDP. The climate change factors consist of temperature and precipitation. Regarding the independent variables, real GDP per capita is used as a proxy for the level of economic development or income, while financial development is measured by the credit-to-private-sector-to-GDP ratio. We used the Brent crude oil price as a measure for the crude oil price, and employed the real lending rate as a proxy for the real interest rate. The data sources mentioned in Table 1 include the Asian Productivity Organisation, the World Development Indicator, and the World Bank Climate Change Knowledge Portal, which may be accessed at https://climateknowledgeportal.worldbank.org/.

Table 2: List of variables, descriptions and data sources

Variables	Description	Sources
$mfgy_t$	Ratio of manufacturing sector's gross domestic product (GDP) to national GDP in RM (constant=2020), to measure (de)industrialization	APO Productivity Database 2022 Version 1
$temp_t$	Maximum temperature, Celsius	World Bank's Climate Change Knowledge Portal
$temp_t^2$	Maximum temperature square	Authors' calculation
$rain_t$	Precipitation, mm	World Bank's Climate Change Knowledge Portal
$rgdppc_t$	Per capita GDP, RM (constant=2015), to proxy for income	WDI
$oilprice_t$	Brent crude oil price (USD). Converted to real RM	U.S. Energy Information Administration
int_t	Real interest rate. Proxy using real lending rate	WDI
$finy_t$	Financial development. Measured using credit to private sector (% of GDP)	WDI

Notes: World Bank WDI database available at https://data.worldbank.org/indicator?tab=all; APO Productivity database available at https://www.apo-tokyo.org/productivitydatabook/

In empirical studies on (de)industrialization, the most widely used indicators are: (1) The share of manufacturing value added in GDP — typically measured as the percentage contribution of manufacturing output to total gross domestic product (GDP), and (2) The share of manufacturing employment in total employment — capturing the percentage of national employment engaged in manufacturing activities. These two indicators dominate the literature because they capture both the output and labour dimensions of structural change (Rowthorn and Ramaswamy, 1997; Palma, 2014; Rodrik, 2016).

The manufacturing-to-GDP share is widely used because it reflects the sectoral contribution to national income, signalling the relative importance of manufacturing in the economy (Dasgupta and Singh, 2007). This measure is available in long time series and across countries, making it suitable for comparative and econometric studies (Felipe et al., 2014). It is particularly useful for assessing productivity-led transformations, industrial upgrading, and the structural shift towards services. On the other hand, the manufacturing employment share complements the output measure by capturing how industrialization affects the labour market. As economies develop, manufacturing employment typically rises, peaking at middle-income stages, and then declines as productivity improvements and services expansion absorb labour (Tregenna, 2016).

Nevertheless, in empirical studies on (de)industrialization, the manufacturing GDP-to-total GDP ratio (often called manufacturing value-added share or MVA share) has emerged as the dominant indicator, compared to the manufacturing employment-to-total employment share, for several key reasons supported by theoretical and empirical evidence. Firstly, it better captures productivity and economic transformation. The manufacturing GDP-to-GDP share reflects not only the scale of manufacturing but also its relative contribution to national income and productivity growth. As Rodrik (2016) argues, manufacturing plays an outsized role in driving aggregate productivity due to its potential for economies of scale, technological spillovers, and learning effects. The GDP share indicator captures these output-side contributions, which are key to assessing structural change, whereas employment shares often miss these dynamics because of sectoral differences in labour productivity. Second, greater data availability and cross-country comparability. International organizations such as the World Bank, UNIDO, and OECD systematically compile long-term, cross-country consistent data on sectoral value added, making the manufacturing GDP share a preferred variable for cross-country empirical studies (Felipe et al., 2014; Tregenna, 2009). In contrast, manufacturing employment data are often missing, inconsistent, or less reliable, especially for developing countries, due to large informal sectors, data gaps, and definitional differences (Rowthorn and Ramaswamy, 1997). Third, avoids biases from labour market changes. Employment-based measures can understate industrial performance in contexts where manufacturing productivity rises but employment declines due to automation, offshoring, or capital deepening (Tregenna, 2016). For example, manufacturing may contribute significantly to GDP and exports even as its labour share falls — a pattern seen in many advanced and emerging economies (Rodrik, 2016). Using employment shares alone would risk misclassifying industrial upgrading as deindustrialization, which makes GDP-based measures more robust in capturing true sectoral shifts (Felipe et al., 2014). Finally, stronger link to policy debates and macroeconomic outcomes. GDP-based measures are more directly linked to macroeconomic policy concerns, such as economic growth, external competitiveness, and resilience to shocks (Dasgupta and Singh, 2007). Policymakers and researchers often prioritize the GDP share because it indicates the sector's contribution to foreign exchange earnings, fiscal revenues, and national income — dimensions central to development strategies. Rodrik (2016) emphasizes that the central challenge of premature deindustrialization is not just the loss of manufacturing jobs, but the shrinking of a high-productivity, tradable sector critical for sustained development. This focus naturally makes the GDP share the central metric in empirical and policy discussions.

3.3 Method of Estimation

The Equation (1) mentioned above is estimated using the Ordinary Least Square (OLS) method. However, the traditional Ordinary Least Square (OLS) method is unsuitable since the time series variables are likely to exhibit autocorrelation and heteroscedasticity. Hence, we use the Ordinary Least Square (OLS) with robust standard error due to the Newey-West (Newey and West, 1987) approach. The Newey-West standard error approach is a robust and reliable estimator that is particularly effective in the face of heteroskedasticity and autocorrelation. Moreover, considering that the time series variables are nonstationary and it is very probable that the regression results may be spurious, we examine the model to see whether cointegration is present. In order to determine whether there is cointegration, we use the standard cointegration test developed by Engle and Granger (1987). The Engle-Granger cointegration test is conducted in two steps. The first step involves estimating Equation (1) using the Ordinary Least Squares (OLS) method. During the second step, the residuals are saved and then examined for the existence of a unit root. If the residuals do not exhibit a unit root, it indicates the presence of cointegration. If the variables are determined to be cointegrated in Equation (1), the estimated long-run models are considered valid, the OLS estimation is efficient, and the results are not spurious.

3.4 Test for Robustness

The crucial inquiry at this point is: How robust are the preceding findings? In order to ensure the reliability of our long-term model, we perform rigorous testing by estimating it using four alternative estimation methods: (i) fully modified ordinary least squares (FMOLS); (ii) dynamic OLS (DOLS); (iii) canonical cointegrating regression (CCR); and (iv) robust regression utilising the M-estimator. The efficiency and robustness of these estimate approaches surpass those of ARDL, especially when dealing with small sample sizes. Phillips and Hansen (1990) first proposed the Fully Modified Ordinary Least Squares (FMOLS) method. The Dynamic Ordinary Least Squares (DOLS) method was later introduced by Stock and Watson (1993). Park (1992) introduced the Common Correlated Effects (CCR) method. The M-estimator in robust regression was popularised by Huber (1964).

The DOLS method addresses the issues of simultaneity and small-sample bias in the regressors by doing a regression analysis where an I(1) variable is regressed on other I(1) variables, I(0) variables, and the lags and leads of the first difference of the I(1) variables. The Fully Modified Ordinary Least Squares (FMOLS) method addresses the issues of small-sample bias, serial correlation, and endogeneity. Prior to estimating a model using the FMOLS, there are two prerequisites that must be fulfilled. First, the model must include a single cointegrating vector. And secondly, there should be no cointegration present among the explanatory variables, as stated by Narayan and Narayan (2004). The CCR applies a fixed transformation to the time series data in order to eliminate two types of biases: (i) the persistent correlation between the cointegrating equation and the innovations of stochastic regressors; and (ii) the simultaneous correlation between the regression and the errors of stochastic regressors, which leads to asymptotic bias (Park, 1992).

Barnett and Lewis (1994) have asserted that the existence of outliers may result in exaggerated error rates and significant distortions of parameter and statistical estimations when using either parametric or non-parametric tests. The increase in error variance has a statistical impact on the power of the statistical tests, normality, and parameter estimations (Perez et al., 2013). Rousseeuw (1984) asserts that robust regression is the optimal approach for identifying outliers and yields outcomes that are resilient to the presence of outliers. The M-estimation technique established by Huber (1964) is the most often used approach for robust regression.

4 The Empirical Results

Prior to testing and estimating Equation (1) for cointegration, we assess the order of integration for each variable, considering that time series variables are non-stationary. We used the conventional augmented Dickey-Fuller (ADF, Dickey and Fuller, 1979, 1981) unit root test to ascertain the level of integration of the variables. For each series, we estimate the variable in level and then in first-difference. The test comprises both the intercept and the intercept with trend. The results of the unit root test for determining the level of integration of the series using the Augmented Dickey-Fuller (ADF) approach are shown in Table 3. The findings of the unit root test clearly reveal that all variables exhibit integrated of order 1, or I(1), meaning that the series become stationary after being differenced once. These findings indicate that all variables exhibit non-stationarity in their level, but become stationary when their first differences are considered. In other words, they are classified as I(0). Therefore, when regressing these integrated variables, it will lead to spurious regression outcomes. When spurious regression findings occur, it means that we cannot draw meaningful conclusions or do accurate hypothesis testing. Therefore, if the variables are not cointegrated, applying OLS to estimate Equation (1) will lead to a spurious regression. A cointegrating regression refers to a long-term model, as defined in Equation (1). Furthermore, it suggests that there are long-run relationship between industrial output and the factors that influence it. Given that all variables exhibit I(1) integration, indicating they have the same order of integration, we may continue with testing for cointegration among the variables using several methods such as the Engle-Granger two-step process, OLS, OLS-robust, Robust M-estimation, FMOLS, DOLS, and CCR.

The cointegration test result for estimating Equation (1) using OLS is reported in

Table 3: Results of unit root tests

	Level		First-difference	
Variables	Intercept	Intercept+trend	Intercept	Intercept+trend
$mfgy_t$	−1.5668(3)	−1.2187(0)	$-3.0187^{**}(2)$	$-5.9205^{***}(1)$
$temperature_t$	−1.0822(2)	−3.2000(2)	$-6.9773^{***}(2)$	$-6.9549^{***}(2)$
$temperature_t^2$	−1.0754(0)	−3.1904(2)	$-6.9778^{***}(2)$	$-6.9563^{***}(2)$
$rainfall_t$	−2.3430(3)	−3.0173(3)	$-8.1881^{***}(2)$	$-8.1107^{***}(2)$
$rgdppc_t$	−2.2885(0)	−1.8528(0)	$-5.5179^{***}(0)$	$-5.9120^{***}(0)$
$oilprice_t$	−2.8517(0)	−2.3233(0)	$-5.9342^{***}(0)$	$-6.1340^{***}(0)$
$interestrate_t$	−2.7393(2)	−2.6560(2)	$-9.5487^{***}(1)$	$-9.5031^{***}(1)$
$finandev_t$	−2.3620(3)	−1.8057(1)	$-4.8456^{***}(1)$	$-5.6081^{***}(1)$

Notes: Asterisks *** denotes statistically significant at the 1% level. Unit root tests were performed using Augmented Dickey-Fuller test. The critical value is referred to MacKinnon (1996). Figures in round bracket, (...) denote optimal lag length. All variables are in logarithm.

column 2 of Table 4. The Dickey-Fuller ($DF_{t\text{-}stats}$) statistic of −3.88 is statistically significant at the 1% level, indicating that the variables are cointegrated or they have long-run relationship, therefore, the estimation of non-stationary variables according to Equation (1) is not affected by spurious problem. The Equation (1) is the estimated long-run model. The OLS-robust regression due to Newey-West estimates is shown in column 3. The presence of serial correlation and heteroscedasticity has been addressed, as shown by the changes in the standard error when compared to the standard error in the traditional OLS.

Our long-run regression analysis indicates that all variables – temperature, temperature squared, rainfall, income, oil price, interest rate, and financial development – significantly influence industrialization in Malaysia. The climate change variables, temperature and temperature square, are statistically significant at the 1% level, indicating a strong relationship. However, rainfall is only statistically significant at the 10% level, suggesting a weaker relationship. The positive impact of temperature and temperature squared on industrialization indicate that the relationship between temperature and industrialization is non-linear. The inverse U-shaped relation between temperature and industrialization implies that lower temperature would promote industrialization. However, when the temperature rises, industrialization experiences a slowdown or reduction in production. The detrimental effect of rainfall on industrialization illustrates that when rainfall intensifies (in the form of intense rainfall showers), it will interrupt business operations and lead to a decline in enterprises' production.

The control variables, income and financial progress, are both statistically significant at the 1% level and exhibit a positive impact. An increase in income and financial development would promote industrialization. However, both oil prices and interest rates,

Table 4: Results on the economic analysis of (de)industrialization

Independent Variables	**OLS**	**OLS-robust** (Newey-West)	**Robust** (M-estimation)	**FMOLS** (lags=1)	**DOLS** (lead=1, lag=0)	**CCR** (lags=1)
Constant	−2808.9***	−2808.9***	−2403.9**	−2443.2**	−4676.1***	−2627.4**
	(−2.8741)	(−2.7463)	(−2.3117)	(−2.6345)	(−2.5365)	(−2.1211)
$temperature_t$	1651.9***	1651.9***	1414.6**	1438.9**	2750.6**	1547.5**
	(2.8841)	(2.7547)	(2.3213)	(2.6475)	(2.5462)	(2.1314)
$temperature_t^2$	−242.85***	−242.85***	−208.11**	−211.79**	−404.22**	−227.73**
	(−2.8937)	(−2.7631)	(−2.3306)	(−2.6595)	(−2.5542)	(−2.1406)
$rainfall_t$	−0.2837*	−0.2837*	−0.2412	−0.3774**	−0.7028**	−0.4697**
	(−1.8820)	(−1.8575)	(−1.5042)	(−2.6383)	(−2.2948)	(−2.2611)
$rgdppc_t$	0.4218***	0.4218***	0.3928***	0.4377***	0.4674***	0.4585***
	(5.7151)	(3.8908)	(5.0020)	(6.2488)	(3.6962)	(5.2801)
$oilprice_t$	−0.0664***	−0.0664***	−0.0622***	−0.0903***	−0.0968***	−0.0897***
	(−3.1110)	(−2.8770)	(−2.7369)	(−4.4564)	(−3.3140)	(−4.5936)
$interestrate_t$	−0.0229***	−0.0229***	−0.0226***	−0.0285***	−0.0505*	−0.0349**
	(−2.9139)	(−3.0482)	(−2.7028)	(−3.8199)	(−1.9638)	(−2.2567)
$finanDev_t$	0.2255***	0.2255***	0.2520***	0.2478***	0.2492***	0.2412***
	(4.5971)	(3.0112)	(4.8283)	(5.3237)	(3.1206)	(5.0072)
$\hat{R}^2$	0.9220	0.9220	0.9535	0.9170	0.9609	0.9130
$DF_{t\text{-}stat}$	−3.8840***					
Optimal (°C)	30.0	30.0	29.9	29.9	30.0	29.9

Notes: Asterisks ***, **, * denote statistically significant at the 1%, 5% and 10% level, respectively. $DF_{t\text{-}stat}$ denotes critical value for Dickey-Fuller unit root test, testing on the residual of the OLS estimated equation. Figures in round brackets, (...) are t-statistics. All variables are in logarithm. Optimal temperature is calculated as $-\alpha_1/2\alpha_2$.

which are statistically significant at the 1% level, have a negative impact. Industrialization will be diminished by an increase in either the interest rate or the price of oil, or by an increase in both.

The robustness of the relationship between industrialization and its determinants, including temperature, temperature square, rainfall, income, oil price, interest rate, and financial development, has been examined. The robust regression M-estimator, fully modified OLS, dynamic OLS, and CCR all provide significant evidence for the existence of a long-run relationship between industrialization and its regressors. In general, temperature has a non-linear or inverted U-shaped effect on industrialization. Rainfall, interest rate, and oil price have a negative influence, whereas income and financial development have positive impact on industrialization.

4.1 Optimal Temperature and (De)industrialization

The model's estimated optimal temperature of ∼30°C, following an inverted U-shaped relationship, suggests that manufacturing output initially benefits from moderate temperature increases, likely due to enhanced metabolic efficiency, longer growing seasons supporting agro-linked industries, or moderate heating cost reductions (Zivin et al., 2018; Dell et al., 2012). However, beyond this threshold, output declines sharply due to escalating heat stress on workers, reduced cognitive and physical performance, increased equipment cooling costs, and energy system inefficiencies (Kjellstrom et al., 2016; Hsiang, 2010). This non-linear relationship underscores the industrial sector's vulnerability to climate extremes, emphasizing the urgent need for adaptive technologies, climate-resilient infrastructure, and heat-mitigating workplace policies (Burke et al., 2015; Somanathan et al., 2021).

Empirical studies across both developed and developing contexts support this finding. For instance, Burke et al. (2015) show that national-level economic output peaks around 13°C globally, though tropical economies like Malaysia experience much higher local thresholds before negative effects dominate, consistent with local climatic adaptation. Zivin and Neidell (2014) find that in the United States, worker productivity in manufacturing declines significantly at temperatures exceeding 27°C, with steeper effects in labour-intensive settings. Similarly, Somanathan et al. (2021) estimate that in India, output losses per day increase sharply beyond 24–26°C, particularly in unorganized, heat-exposed manufacturing.

Contrasting evidence also exists: Heal and Park (2016) suggest that high-income economies can buffer temperature shocks through adaptation, mechanization, and technological shifts, reducing the turning point's economic damage compared to developing economies. Dell et al. (2012) further shows that in cooler, temperate countries, moderate warming might raise agricultural productivity and spill over into related manufacturing, although this benefit disappears in hotter countries, where any additional heat reduces overall growth. Thus, your study's identification of a ∼30°C optimal point situates Malaysia within the global pattern of tropical economies, where extreme temperatures impose pronounced risks on industrial performance. Importantly, it reinforces the policy relevance of investing in energy-efficient cooling systems, heat-tolerant labour standards, and supply chain resilience as temperatures continue to rise.

5 Conclusion

In the last 50 years, Malaysia has seen a decline in industrial activity, known as deindustrialization, despite its previous strong efforts in industrialization. Deindustrialization is the process of the progressive decrease in the importance of manufacturing industries in the economy, usually accompanied by a transition towards services and other sectors. Regrettably, Malaysia's deindustrialization has been categorised as premature deindustrialization since the manufacturing sector's contribution to the country's GDP achieves its peak below the threshold level seen in industrialised nations.

The objective of this study is to analyse the influence of climate change on the deindustrialization process in Malaysia between 1970 and 2020. The climatic change variables were denoted by temperature and precipitation, whereas deindustrialization was quantified by the ratio of manufacturing output to total gross domestic product. We used five estimators to assess the impact of climate change on deindustrialization, namely the Ordinary Least Square (OLS) technique with robust standard error, Robust regression with M-estimator, FMOLS, DOLS, and CCR. The study incorporates control factors such as income, crude oil price, real interest rate, and financial development. Overall, our results suggest that extreme weather events, such as extreme heat and heavy rainfall, accelerate the deindustrialization process in Malaysia. Conversely, an increase in the price of crude oil and the real interest rate has an adverse effect on industrialization. On the other hand, a rise in the degree of economic growth and financial development has positive impact on industrialization. Our findings align with studies showing non-linear temperature effects on economic productivity (Burke et al., 2015; Zivin et al., 2018) and the negative impact of high oil prices on manufacturing output (Hamilton, 2009). The results on financial development echo Levine (2005), who emphasizes credit availability's positive role in sectoral growth.

Given the evidence of the impact of climate change on industrialization in Malaysia, a significant policy consequence of this study is that the government should initiate an investment development programme that prioritises environmentally sustainable practices for future growth. All stakeholders in the development process, including the financial institutions that provide funding, must possess a comprehensive understanding of the risks associated with climate change, such as changes in temperature and precipitation patterns, as well as the increased occurrence of extreme weather events leading to frequent natural disasters. Furthermore, it is imperative that these parties incorporate specific criteria for reducing greenhouse gas emissions at every stage of the development. Financial institutions and prospective borrowers should both be held to certain standards in order to protect against and reduce the risk of environmental damage caused by project development and investment. In addition, it is necessary to enhance the national policies and action plans aimed at achieving zero carbon emissions, as well as preserving and restoring carbon reserves in order to prevent the deterioration of the environment and ultimately help combat climate change.

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