CHEMICAL ENGINEERING TRANSACTIONS
VOL. 103, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Petar S. Varbanov, Panos Seferlis, Yee Van Fan, Athanasios Papadopoulos

ISBN 979-12-81206-02-1; **ISSN** 2283-9216
DOI: 10.3303/CET23103105

Enabling Circular Practices in the Manufacturing Industry: Barriers and Challenges

Sue Lin Ngan*, Puan Yatim, Roslan Ja'afar

UKM-Graduate School of Business, Universiti Kebangsaan Malaysia 43600 UKM, Bangi, Selangor, Malaysia
suelin.ngan@ukm.edu.my

Circular Economy has been an integral part of the sustainability agenda and contributed to several different Sustainable Development Goals (SDGs), particularly SDG 12, Responsible Consumption and Production. Malaysia ranked fourth among seventeen economies in terms of its competitiveness as a manufacturing hub which contributes about 23 % to its GDP. It is imperative that the manufacturing sector in Malaysia takes the lead in promoting circular business models across its entire value chain. As the uptake of circular economy practices in the manufacturing sectors remains low, this work aims to understand the extent of the awareness of the circular economy and the adoption of circular principles in the manufacturing sector in Malaysia. The findings show that more than two-thirds of the respondents are familiar with the circular economy concepts. In general, the respondents are highly aware of the economic benefits of the circular economy, particularly when they consider risk factors associated with the scarcity and costs of raw materials as well as supply chain issues. The study also identifies barriers and challenges faced by the industry players in transitioning towards the circular economy. These barriers and challenges include financial and economic constraints, lack of technical and technological capacity and capabilities, organisational and institutional factors, fragmented green-growth policies and initiatives, and lack of industrial integration and support. The findings can serve as a reference to recommend best practices for the manufacturing sector to move towards the circular economy principles and help policymakers to design general standard operating procedures for the implementation of the circular economy in Malaysia.

1. Introduction

In recent years, Circular Economy has garnered increased attention among industry participants, policymakers as well as researchers. While there is ongoing debate regarding the definition and scope of the circular economy, it is widely believed to be an approach that fosters a sustainability paradigm by tackling resource scarcity and environmental issues. In general, Circular Economy promotes efficient use and reuse of resources resulting in lower input materials, energy, emissions, and waste leakages, reducing environmental impacts without jeopardising development, growth, and prosperity. Kirchherr et al. (2017) emphasise that the concept of circular economy is closely linked to systemic change and can be implemented at the micro-level (firm-level), meso-level (industry-level), and macro-level (national) as an economic framework. The key principle of the Circular Economy includes waste and pollution elimination (Varbanov et al., 2021), maximising resource utilisation, and regeneration of natural systems. Although an extensive range of topics and issues related to the circular economy has been researched and incorporated into the existing literature, Lahti et al. (2018) argue that there is a significant lack of research focusing on enabling companies to implement circular economy principles within their regular business operations effectively. The emerging economies, which accounted for 50 % of global GDP and 66 % of the global GDP growth over the past 10 y (2012-2022), are anticipated to remain key drivers of the world economy in the coming decades (World Economics, 2022). It is imperative for the economic growth driven by these emerging markets are supporting sustainable development, including the incorporation of circular economy principles in the business models. Parida et al. (2019) highlight that manufacturing companies can benefit significantly from the adoption of circular economy principles in their production and consumption planning and management. In 2022, the manufacturing industry in Malaysia contributed to about 23.5 % of the

Paper Received: 14 March 2023; Revised: 30 May 2023; Accepted: 23 July 2023
Please cite this article as: Ngan S.L., Yatim P., Ja'afar R., 2023, Enabling Circular Practices in the Manufacturing Industry: Barriers and Challenges, Chemical Engineering Transactions, 103, 625-630 DOI:10.3303/CET23103105

national GDP, amounting up to MYR 1,609.3 billion and provided 2.3 million employment opportunities (DOSM, 2023). Malaysia has started its green growth efforts since the 1980s by instituting policies that promote and facilitate green growth and the greening of industries and circular principles. Current policy actions and initiatives to promote sustainability have focused primarily on energy policies, waste management, and bioeconomy. While linearity is deeply institutionalised, the policy recommendations in the recently released Twelfth Malaysia Plan (MP) emphasise the need to transition to the Circular Economy. Circular business models such as circular supply chain management, recovery of usable resources or energy from waste or by-products, collaborative value chain, and product life extension, when applied to the manufacturing sector, can reduce input material costs, wastes, and other inefficiencies and create value for manufacturing companies (Acerbi and Taisch, 2020). Against this background, this work focuses on understanding the awareness and acceptance level of the manufacturing industry players on the concept of circular economy. The study also identifies factors that affect the companies' propensity to transition to Circular Economy and barriers and challenges that hinder industry players in transitioning toward the Circular Economy.

2. Literature review

Malaysia started its sustainable development initiatives since the 1970s when the New Economic Policy was introduced to eradicate poverty and restructure societal imbalance. In 2009, Malaysia put forth New Economic Model, which further affirmed Malaysia's commitment to pursue sustainable development based on three goals: high income, inclusivity, and sustainability. The 10th MP (2011-2015) recognised the importance of environmental sustainability as part of a comprehensive socio-economic development plan. Under the 10th MP, several initiatives anchored upon the Renewable Energy Policy and Action Plan were undertaken, including the implementation of Feed-in-Tariff (FiT). Since the FiT mechanism was introduced, a total of 1,423.96 MW quotas have been approved for all renewable sources involving 10,480 projects nationwide in 2022 (SEDA, 2022). The growth in renewable energy utilisation is in line with the nation's goal to boost the deployment of renewable energy sources while supporting the target of 31 % installed capacity of renewable energy by 2025 and 40 % by 2035 (SEDA, 2022). In the Eleventh MP (2016-2020), the government continued to step up green growth efforts by integrating sustainable economic development and enhancing environmental sustainability in order to achieve a resilient, low-carbon, and resource-efficient economy. In pursuing green growth, the enabling environment was strengthened, particularly in policy and regulatory framework, human capital, green technology investment, and financial instruments (EPU, 2016). In the Twelfth MP (2021-2025), efforts will be undertaken to ensure further that development policies and policy implementations continue to align with socio-economic development imperatives and environmental sustainability. Under the third theme of the Twelfth MP, Advancing Sustainability emphasises socioeconomic policies that take into account environmental sustainability aiming to achieve sustainable growth, enhance resource efficiency, and preserve ecosystem resilience. Advancing Sustainability theme also promotes the adoption of the circular economy and streamlines energy related-policies as well the adoption of integrated water resource management (IWRM) (EPU, 2021). In 2018, the Ministry of Housing and Local Government launched the 2018-2030 roadmap towards zero single-use plastics, which is the first policy adopting CE principles to tackle the plastics waste problems in the country (MESTECC, 2018). The initial Circular Economy roadmap will be introduced in 2020 as the second implementation phase of the roadmap. It was superseded by the Malaysia Plastics Sustainability Roadmap 2021-2030, which outlines strategies and action plans to achieve greater plastic circularity levels in Malaysia. Some of the key strategies aligned with the principles of the circular economy include improving collection and sorting facilities for recycling and reuse, increasing recovery rates throughout the production chain to establish a closed-loop supply chain, and rethinking packaging and product design business models (KASA, 2021). The series of initiatives show the Government's clear intent on promoting the concept of a Circular Economy in the economic development agenda. Nonetheless, the uptake of circular principles in the manufacturing industry in Malaysia remains limited. This is partly due to the lack of ecosystem partners, which poses a significant challenge for manufacturing firms in attaining a successful circular economy transformation (Patwa et al., 2021). This work aims to investigate the key factors that hinder industry players from integrating Circular Economy principles in their production process to enable policymakers to introduce effective measures to boost the uptake of circular principles in the manufacturing industry for conserving resources and sustainable development.

3. Methodology

In this work, a mixed method is employed to understand the awareness and acceptance level of the manufacturing firms and the motivations and challenges that encourage or hinder the implementation of circular economy principles in their business models. The first stage of the work focuses on the development of the questionnaire. A comprehensive literature review is conducted to identify circular economy key principles and

practices and possible benefits and challenges that support and/or hinder the adoption of circular economy principles in the manufacturing sector. A panel discussion was held with the government agencies, manufacturing firms as well as non-governmental agencies which are driving the sustainability initiatives in Malaysia to attain first-hand information on some of the issues that they are facing in accelerating the adoption of circular economy principles in Malaysia. These inputs contribute to the development of the online questionnaire, which is the key instrument for data collection in this study. An online questionnaire was distributed via e-mail to manufacturing companies involved in three sub-sectors, namely chemical, electronics, and electrical (E & E) and machinery and equipment (M & E). The first section of the questionnaire, containing 9 questions, relates to the demographics of the respondents, while the second section, consisting of 11 questions, explores the level of awareness towards the Circular Economy. The third section inquires the respondents about their current and future plans regarding the implementation of circular economy practices within their companies. The fourth section focuses on identifying and evaluating the enabling factors and opportunities that facilitate the adoption of circular economy practices in the company's production and manufacturing processes. This section consists of 5 overarching questions with 21 sub-questions. The last section of the questionnaire, comprising 7 questions with 36 sub-questions, aims to identify barriers encountered by companies when implementing the circular economy. All questions in the questionnaire are closed-ended questions (i.e., single-select multiple-choice questions and multi-select multiple-choice questions). A pilot test was conducted to ensure the validity and reliability of the measurements selected, as well as the appropriateness of the word used in the questionnaires. To prevent sampling bias (i.e., self-selection bias), the questionnaire is also translated into Malay language and proofread by a native Malay language speaker as it is the national language and the first language of most of the population in Malaysia. Due to the higher concentration of manufacturing activities located in Klang Valley, Penang Island and Johor industrial areas were selected for the survey. The sampling frame consisting of manufacturing firms in these three locations is gathered with the help of the Malaysian Productivity Corporation (MPC), a government agency focusing on organisations for productivity and competitiveness. The online questionnaire in the form of Google Forms is distributed to the respondents through email. As the implementation of the circular economy principles in the business model represents a strategic decision, only the top management and the senior executives who take part in the strategic decision-making process are selected as the target respondents. Several follow-up emails were sent to encourage the participation of the respondents in this survey. Phone-administered and mail-administered questionnaires are also carried out upon request by the respondents. The collected data are cleaned, coded, and filtered to eliminate non-response inputs or illogical inputs with Microsoft Excel. The data analysis started with the verification of the identity of the respondents through publicly available information (i.e., company website, email, company's annual report) to assure the respondents are the target audience for this study. A descriptive analysis consisting of measures of central tendency, measures of variability, and frequency distribution is then performed to present the results. The weights of the responses for each question are presented in percentages for easy reference and comparison. Focus group discussions are also conducted to understand and gauge the detailed factors that hindered the uptake of circular economy principles. The focus group discussion also helps in providing constructive feedback and recommendations for the manufacturing industry to facilitate a successful transition towards the circular economy.

4. Results and discussion

This section reports results related to the circular economy initiatives undertaken by a company in the last 3 y. The respondents were requested to identify the current circular economy initiatives undertaken by their respective companies based on the four options (i.e., Yes, activities have been implemented; Yes, activities are underway; No, but we plan to do so; No, and we do not plan to do so). The seven circular economy practices are i. Re-plan the way water is used to minimise usage and maximise re-usage, ii. Use of renewable energy sources in manufacturing processes, iii. Re-plan energy usage to minimize consumption during manufacturing processes, iv. Minimise waste by recycling or reusing waste or selling it to another company, v. Redesign products and services (i.e., eco-design, green packaging) to minimise the use of materials or use recycled materials, vi. Practice green procurement or purchasing of raw materials/production inputs, vii. Engage with suppliers and customers in circularity initiatives. Based on the valid 140 survey responses, Figure 1 shows that waste minimisation through recycling, reusing waste, or selling waste to another company appears to be the most common approach undertaken by companies (51.2 %) relative to other circular economy initiatives. Waste minimisation through recycling, reusing waste, or selling it to another company is also common among companies with a weight of 27.3 %. Circular economy initiatives such as the use of renewable energy sources, re-plan energy usage, redesigning products, and services, implementing green procurement of raw materials and production inputs, as well as engaging with supplies and customers in circular activities, appear to be at the initial implementation state or planning stage.

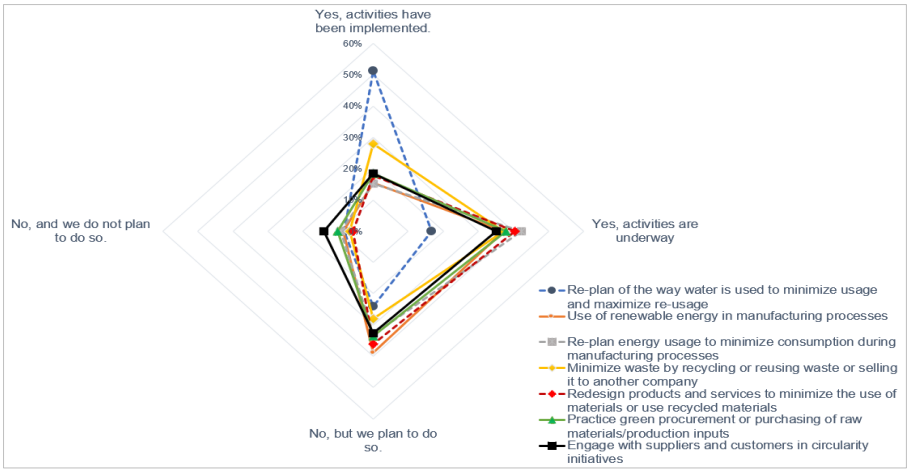

Figure 1: Circular economy initiatives undertaken in the last 3 y

The survey results also show that reduction in waste generation and accumulation (64.4 %) and potential for gaining competitive advantage in the market (48.9 %) are the key factors that incentivise manufacturing-related firms to embrace circular principles within their business models. The integration of sustainability principles into their business process and corporate strategy (39.3 %) ranked third in the factors that potentially affect the companies' propensity to transition to Circular Economy, followed by venturing into new markets (25.9 %) and communicating and improving corporate image and public relations (23.0 %). It is worth noting that increasing the production efficiency of utility (i.e., water, electricity) consumption and reducing utility cost through optimising and enhancing the efficiency of energy, water, and resource usage are the top two factors in motivating manufacturing companies to implement circularity design in their existing manufacturing process, as indicated by 77.3 % and 75.7 % of the responses returned. The fiscal and monetary incentives and supports from the government also appear to play a significant role in driving companies to transition to Circular Economy (76.7 %). Factors related to regulation and compliance in meeting national and international environmental management standards also drive companies to move towards circularity (75.9 %). Foster and increasing awareness of best waste management practices among employees, customers, suppliers, and other stakeholders through clean production and product design in risk drivers are also rated as one of the key drivers in motivating the company towards a Circular Economy (76.0 %). Although significant efforts have been made to highlight the potential economic and environmental advantages of the circular economy, the findings on the key drivers provide valuable insights for top management and managers of traditional manufacturing firms seeking to incorporate CE principles into their business models gradually. In terms of the barriers hindering manufacturing firms to uptake circular principles, economic and financial barriers ranked first with 76.6 % of responses, followed by organisational barriers (56.2 %), technological barriers (35.8 %), institutional barriers (16.8 %), environmental barriers (16.1 %) and social barriers (14.6 %). The transition to circular manufacturing involves systemic changes to the production design and process associated with high upfront costs to modify or restructure the existing plant. Due to the relatively new concept of circular economy, research and development cost, and consultation costs are expected to be incurred to ensure consistent performances of the circular manufacturing and equip human resources to maintain and operate the system (Ormazabal et al., 2018). Uncertainties surrounding consumer acceptance and demand for "green" products, investment costs, and return on investment (ROI) further amplify the challenges in securing financing or investment from financial institutions or investors (Al Mamun et al., 2018). The lack of technical and technological capacity to embrace the concept of circular economy is another barrier to transition towards the Circular Economy. Technology plays a prominent role in circular manufacturing in the regenerative resources process (i.e., waste management, renewable energy) as well as optimization of the utilization of resources (i.e., water, energy) (Klemeš et al., 2021). Circularity-incorporating technologies have reached a state of maturity in developed nations, and newly emerging technologies can be costly for manufacturing companies in developing countries to obtain. This presents a barrier to the implementation of the Circular Economy. While research has confirmed the feasibility of a closed material loop design, technological gaps, such as the time lag between invention and actual production, scalability, and the availability of skilled personnel remain challenges in realising successful circular manufacturing (de Jesus and Mendonça, 2018). To optimise resource utilisation as per the principle of circular economy, the use of digital manufacturing technologies to provide real-time data to monitor and design planned predictive maintenance schemes has become increasingly important.

Table 1: The average value of the degree of impact of factors that drive company's decision-making to implement circular economy principles.

Driver	Descriptions	Percentage
Economics	• Reduce waste management and disposal costs	75.43 %
	• **Reduce utility costs by optimising energy, water, and resource usage**	**75.71 %**
	• Unlock revenue potentials gained from niche markets and consumers (i.e., environmentally conscious customers or "green" consumers)	73.29 %
	• Improve revenue potentials by implementing resource recovery in the production process (i.e., use of by-products and conversion of waste into production inputs)	74.14 %
Environmental	• Accessibility and availability of non-renewable resources for the production process	71.86 %
	• Ability to manage and mitigate the scarcity of raw materials for the production process	73.86 %
	• Reduction of wastes generated from the production process	75.43 %
	• Reduction of environmental footprints (i.e., carbon, water, land footprints)	74.71 %
	• **Increase production efficiency of utilities (i.e., water, electricity) consumption**	**77.29 %**
Stakeholder	• **Fiscal and monetary incentives and support from the government**	**76.71 %**
	• **Regulatory compliance to meet national and international environmental management standards**	**75.86 %**
	• Pressure from stakeholders (e.g., NGOs and international organisations) for companies to be environmentally responsible and adopt clean production practices	70.86 %
	• Avoidance of monetary penalty due to non-compliance with environmental regulations and standards	74.00 %
Risk	• Reduce supply chain risk due to less dependence on the procurement of production inputs from suppliers	73.57 %
	• Reduce supply chain disruption due to the circularity model embedded in the production process	72.43 %
	• Reduce negative environmental impacts due to additive manufacturing practices or adoption of a circularity approach in the production process	73.71 %
	• **Foster and increase awareness of best waste management practices among employees, customers, suppliers and other stakeholders through clean production and product design**	**76.00 %**
	• Reduce reputational risk associated by complying of environmental standards and waste management and disposal rules and regulations	75.57 %
	• Increase of costs associated with compliance with environmental standards, waste management and disposal rules and regulations	74.43 %
	• Increase in business risk due to consumer's perceived low quality of the "green" products	71.14 %
	• Decrease of business risk due to consumer's acceptance of clean or green consumption	71.71 %

Lack of access to affordable digitalisation platforms and knowledge and skills within the organisation in data analytics and data governance served as the technical challenges to adopting the Circular Economy model. "Soft" barriers, such as organisational and institutional barriers, also contribute to the slow transition to the Circular Economy. For instance, a lack of effective corporate communication within the organisation on the awareness and the need for waste management and sustainable development could result in poor morale and low efficiency in adapting to new changes in transitioning to a Circular Economy (Singh and Ordoñez, 2016). Lack of interest, awareness, and information on the environmental impacts of waste management and disposal methods from the company's management also increases the difficulties in realising the successful implementation of the Circular Economy.

5. Conclusion

In order to facilitate a systemic shift towards the circular economy, it is recommended that manufacturing firms integrate circular economy principles synergistically within their business strategy to ensure the effectiveness of their business model. Circular Economy aims to convert both the biological and technical resources associated with the manufacturing process into a circular cycle to keep the resources at their highest utility and value at all times. It is recommended that the company maintain, repair, and upgrade resources in use to maximise their lifetime and give them a second life through take-back strategies, where applicable. In the situation in which regenerative resources are applicable, it is imperative to make sure that renewable, reusable resources are prioritised over virgin resources. The transition toward a circular economy indeed requires the close collaboration of all industry stakeholders within the ecosystems, both the peers within the industry, R&D and academic institutions, government agencies, and NGOs to mitigate and manage the barriers and challenges, on uncertainties of the technology's performances, scalability, operational expenditure, and technical resources. While the small sample for this work might not allow generalisation of the results across different industries, the survey results obtained in this study provide helpful insights to manufacturing firms and other implementing

agencies to overcome barriers and take advantage of the economic and environmental benefits of circular economy by, among others, designing fiscal benefits and incentives for technological innovation to promote and support manufacturing firms to accelerate their transition towards a circular economy. The findings also help manufacturing firms put in place education and training programs to address organisational hesitancy and foster a greater willingness to engage in the circular economy. Future work will focus on conducting life cycle assessment of the manufacturing companies which adopted circular principles to quantify the impacts (e.g., resource-saving, waste reduction, pollution reduction) to further encourage the uptake of circular economy in the manufacturing sector, especially in developing countries context.

Acknowledgements

The authors would like to thank Universiti Kebangsaan Malaysia (Grant number: GGPM-2022-075 and GP-2021-K023353) for the funding of this research.

References

Acerbi F., Taisch M., 2020, A literature review on circular economy adoption in the manufacturing sector. Journal of Cleaner Production, 273, 123086.

Al Mamun M., Sohag K., Shahbaz M., Hammoudeh S., 2018, Financial markets, innovations and cleaner energy production in OECD countries. Energy Economics, 72, 236–254.

de Jesus A., Mendonça S., 2018, Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy. Ecological Economics, 145, 75–89.

DOSM, 2023, Annual Economic Statistics (AES) Manufacturing 2022. Department of Statistics Malaysia, Putrajaya, Malaysia.

EPU, 2016, Eleventh Malaysia Plan 2016-2020, Economic Planning Unit, Putrajaya, Malaysia, <ekonomi.gov.my/sites/default/files/2021-05/Chapter%201.pdf>, accessed 19.04.2023.

EPU, 2021, Twelfth Malaysia Plan 2021-2025, Economic Planning Unit, Putrajaya, Malaysia. <https://rmke12.ekonomi.gov.my/en>, accessed 19.04.2023.

Kirchherr J., Reike D., Hekkert M., 2017, Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221–232.

Klemeš J.J., Fan Y.V., Jiang P., 2021, Plastics: friends or foes? The circularity and plastic waste footprint, Energy Sources, Part A: Recovery, Utilization and Environmental Effects, 43(13), 1549-1565.

Lahti T., Wincent J., Parida V., 2018, A definition and theoretical review of the circular economy, value creation, and sustainable business models: Where are we now and where should research move in the future? Sustainability, 10, 2799.

MESTECC, 2018, Malaysia's Roadmap towards Zero Single-use Plastics 2018-2030: Towards a sustainable future. Ministry of Energy, Science, Technology, Environment & Climate Change, Putrajaya, Malaysia. <pmo.gov.my/ms/2019/07/pelan-hala-tuju-malaysia-ke-arah-sifar-penggunaan-plastik-sekali-guna-2018-2030/>, accessed 19.04.2023.

KASA, 2021, Malaysia Plastics Sustainability Roadmap 2021-2030, Ministry of Environment and Water, Putrajaya, Malaysia. <thecirculateinitiative.org/projects/Malaysia-plastics-sustainability-roadmap-2021-2030>, accessed 19.04.2023.

Ormazabal M., Prieto-Sandoval V., Puga-Leal R., Jaca C., 2018, Circular Economy in Spanish SMEs: Challenges and opportunities. Journal of Cleaner Production, 185, 157–167.

Parida, V., Burström, T., Visnjic, I., Wincent, J., 2019, Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing companies. Journal of Business Research, 101, 715–725.

Patwa N., Sivarajah U., Seetharaman A., Sarkar S., Maiti K., Hingorani K., 2021, Towards a circular economy: An emerging economies context. Journal of Business Research, 122, 725–735.

Singh J., Ordoñez I., 2016, Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. Journal of Cleaner Production, 134, 342–353.

Sustainable Energy Development Authority (SEDA), 2022, 32 Companies Awarded Fit Quotas, set to Generate RM1.14 Bil Investment. <seda.gov.my>, accessed 23.03.2023.

Varbanov P.S., Chin H.H., Jia X., Sher F., Klemeš J.J., 2021, Environmental Impacts of Plastic Materials Flow Minimisation Using Data-Driven Pinch Method. Chemical Engineering Transactions, 88, 967-972.

World Economics, 2022, Emerging Markets: 24 Countries Make Up the Emerging Markets. <worldeconomics.com/Regions/Emerging-Markets/#:~:text=World Economics has combined 24, years (2012-2022)>, accessed 04.03.2023.