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Integrating policy, technology, and knowledge: a roadmap to circular manufacturing adoption

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ABSTRACT

Circular Manufacturing (CM) is a manufacturing process that employs strategies such as remanufacturing and closed-loop supply chains to improve sustainability (Delpla, Kenné, & Hof, 2022). This process employs circular economic principles. The adoption of CM has been impeded by a lack of financial support, inadequate consumer awareness, and insufficient government support. This review aims to facilitate a broader understanding of the adoption of government policies in implementing circular manufacturing strategies, which will help in advancing our knowledge about how nations compete to create and capture value. To provide a comprehensive and global perspective, the review included 524 studies from the Scopus Database, covering studies between 1990 and May 2024. The review contributes to (a) outlining three thematic clusters of shared scholarly interest, (b) the conceptual framework, and (c) highlighting several areas for future research. Ineffective management and sharing of information are significant challenges that impede organisational knowledge and decision-making administration. The transition to CM is facilitated by identifying essential data and technologies through an integrative review (bibliometric analysis and conceptual framework).

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KEYWORDS
Circular manufacturing; sustainability; circular economy; innovation; conceptual framework

1. Introduction

Over the past century, CO2 emissions have risen uncontrollably. This, combined with excessive resource consumption, threatens the planet's survival if left unchecked. This issue was perceived as a significant problem that society as a whole should address in research dating back to the 1960s (Boulding 2013). Consequently, the term 'sustainability' first appeared in the late 1970s in the literature, even though the concept of sustainability is quite ancient (Caradonna 2022). In addition, policymakers began advocating for "sustainable development', which is founded on environmental, economic, and social pillars (Elkington, Henriques, and Richardson 2004), in recognition of the significance of these issues. Policymakers worldwide have begun to promote the adoption of a circular economy – an industrial economy dedicated to the regeneration and restoration of resources. This approach is regarded as a significant factor for the advancement of manufacturing sustainability. The most recent iteration of the action plan was the last time the European Commission had confirmed its stance. Countries worldwide, including China (Zhu, Geng, and Lai 2010), Australia (Pagotto and Halog 2016), and the United States (Ranta et al. 2018), are also promoting circular initiatives.

The circular economy is based on cycles designed to extend the lifecycle of a product by slowing, narrowing, and closing resource loops (Bocken et al. 2016) across biological, technical, or informational domains (Valkokari et al. 2019). If this approach is put into practice in manufacturing organisations, it is known as Circular Manufacturing or CM (Acerbi and Taisch 2020; Acerbi et al. 2021). Circular Manufacturing (CM) is a manufacturing process that employs strategies such as remanufacturing and closed-loop supply chains to improve sustainability. This is the simultaneous interplay between different resource conservingor cycling strategies. This includes design, manufacturing, consumers, and regulatory authorities that enable resource saving, resource extension, and consumption convergence. The systematic literature review SLR conducted by Acerbi and Taisch (2020) unearthed patterns in the following CM strategies: reuse, circular design, recycling, disassembly, remanufacture, cleaner production, industrial symbiosis, resource efficiency, reverse logistics, waste management, and closed-loop supply chain. These strategies necessitate a significant socio-technical transformation and facilitate conformity of the manufacturing sector with sustainable development objectives (Schot and Steinmueller 2018).

They are further categorised into several types. Economic and financial stem from restricted financial resources and limited businesses support. Social barriers arise due to lack of limited consumer awareness. Institutional barriers result from insufficient government backing., Technological and informational barrier are linked to inadequate sharing of knowledge and information sharing. Organisational and attitudinal barriers emerged from a siloed approach and resistance to change. Operational barriers relate to the lack of network support and insufficient developed partnership across the supply chain (Ritzén and Sandström 2017; Tura et al. 2019). Most studies

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agree with the adoption of (CM). However, the management and sharing of information remains among the most critical challenges, leading to a lack of support for decision-making processes that require data and information standardisation (Halstenberg, Lindow, and Stark 2017). The lack of data flow is often a major issue for organisations, creating a siloed environment that limits the effectiveness of knowledge management (KM) practices in promoting a well-structured and cohesive internal organisation. Moreover, data scarcity hampers the selection of suitable partners for resource exchange within an industrial symbiosis network, as illustrated in the context of CM (Grieves 2005).

In addition, insufficient data may affect the choice of the best possible option that can be used to extend the life cycle of the resources within the scope of the investigation. Collecting data on the end-of-life stages of a product's lifecycle is essential. This information helps identify potential design flaws. By addressing these flaws, future product generations can be improved. (Marconi and Germani 2017). This study seeks to support the embracing of government regulations on circular manufacturing strategies by providing an integrative review. Despite the presence of existing SLR, it is necessary to conduct an integrative review (bibliometric analysis and conceptual framework). The aim of this study is to provide a structured and comprehensive explanation of how to overcome this policy management barrier. Sassanelli et al. (2019) and Sassanelli and Terzi (2023) focus on examining how advancements in technology can facilitate the establishment of circular systems. Farooque et al. (2019) discussed the characteristics of the adoption of circular economy-based government policies in manufacturing and the structure of a specific strategy.

Consequently, it is imperative to investigate the necessary data and information to be collected to implement each CM strategy-based policy and associated supporting technologies. This will be achieved by implementing various CM strategies based on data exploitation. The research questions (RQ) that are addressed to attain the paper's objectives are as follows: *RQ1: "What are the thematic clusters in the literature on the adoption of government policies in CM?" RQ2: "What is the conceptual framework defining the literature on the adoption of government policies in CM?". RQ3:"What are the future avenues on adopting government policies in CM?"* This analysis provides an overview of the present state of knowledge in this area, highlighting gaps in the literature and suggesting avenues for future research. The findings from this review will contribute to a deeper understanding of how government actions can best support the manufacturing sector, thereby informing more effective policy making and strategic planning.

2. Methodology

This study employs an integrative review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Lucey, Kumar, and Sureka 2023; Page and Moher 2017). Our dual-pronged methodological approach encompasses a bibliometric analysis with a subsequent conceptual framework, providing a holistic summary of the existing literature. VOSviewer (Van Eck and Waltman 2014) software was used to perform the co-occurrence analysis of keywords to identify key topics and thematic clusters, while content analysis identifies key theories that set a baseline for future research (Donthu et al. 2021; Paul et al. 2021) in Figure 1.

This process begins with the development of a comprehensive search string for data retrieval. The search string thus formed is TITLE*"circular manufacturing; government policies; manufacturing growth; regulations; and 'incentives'*. Articles published between 1990 and May 2024 in Journal were selected. This review included studies from both developed and developing countries to provide a global perspective. This study uses the Scopus database (Paul et al., 2021) to retrieve the relevant corpus for policy, regulations, and incentives for manufacturing research. With the search mentioned above, Scopus initially provided 1883 results. We applied year filtration from 1990 to 2024 and left 1748. The results were again filtered according to the subject areas of engineering/computer science/business management: 1037; journal/article: 705; English: 646. This resulted in 646 articles. All these documents need to go through a proper peer-review process to match the scope of the research questions. Finally, we had 524 documents to include with us.

3. Findings

3.1. Publication trend

The number of publications during this period was relatively low, with occasional spikes (e.g. 1996–1997). This could indicate an early academic or industrial interest in the foundational concepts of sustainability, resource efficiency, and closed-loop production. This trend remained relatively stable with moderate fluctuations. While there is some progress, this reflects a phase in which awareness about sustainability was growing but had not yet become a primary focus for research. From approximately 2010 onward, there was a noticeable upward trajectory in the number of publications (Figure 2). Global recognition of sustainability challenges (e.g. climate change and resource depletion). Increased adoption of frameworks such as the Circular Economy by governments, industries, and academic institutions. The sharp growth in publications after 2020 indicates a significant acceleration in the interest and research in circular manufacturing. Global policy shifts, such as the European Green Deal and sustainability mandates by international organisations. Industry-driven innovation for decarbonisation and resource recovery. The heightened awareness of supply chain vulnerabilities during and post-COVID-19 pandemic has driven interest in resilient manufacturing systems. The apparent decline in 2024 May be due to incomplete data for the year, as the figure likely captures publications up to the current date, rather than the entire year.

3.2. Keyword analysis map

The co-word analysis of keywords that authors enlist in their publications reveals three distinct co-word (thematic) clusters consisting of 51 keywords that characterise the body of

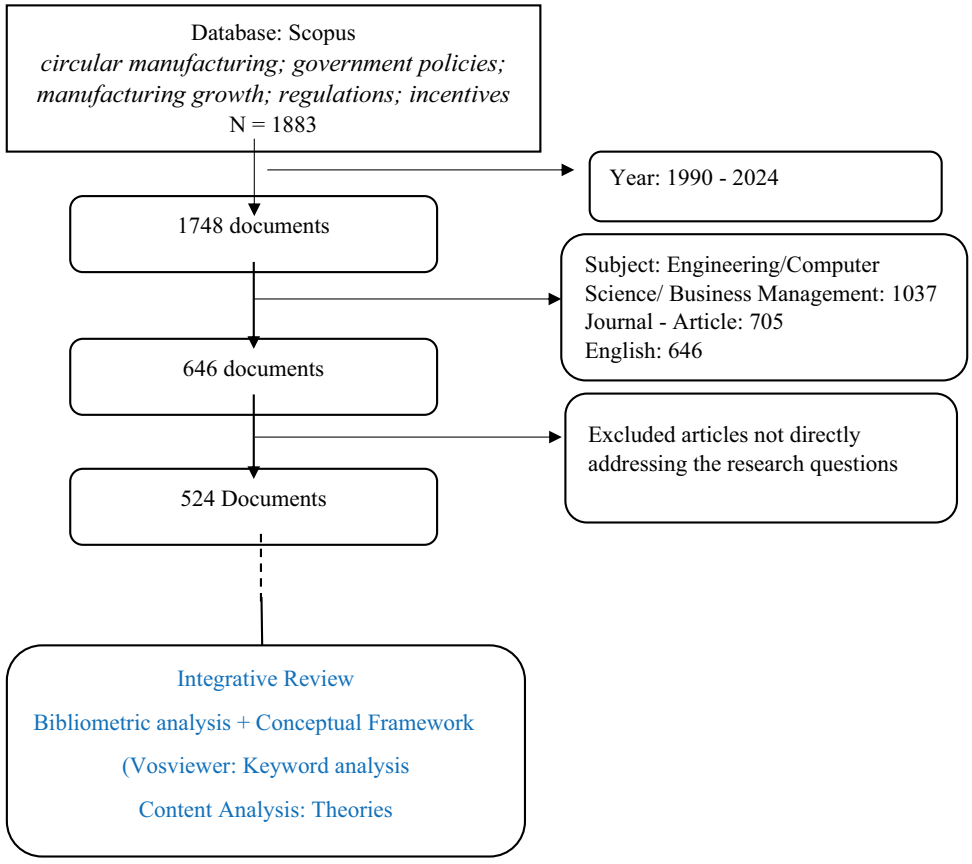

Figure 1. Data retrieval process and methodological structure.

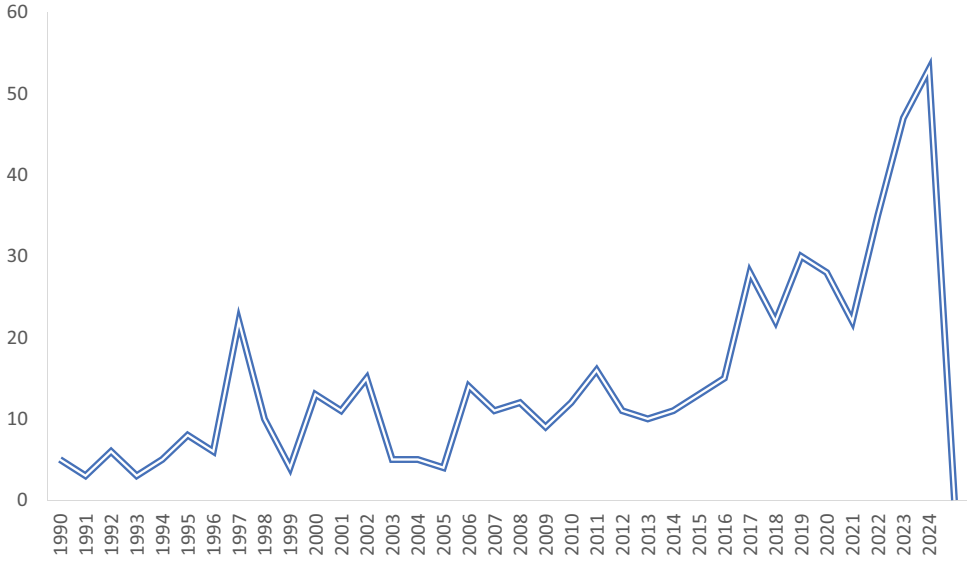

Figure 2. Publication trend from 1990 till 2024.

knowledge of the literature on the adoption of government policies in CM, as shown in Figure 3.

The first cluster is named as *'Manufacturing Systems and Maintenance'*. This cluster encompasses the design, operation, and maintenance of the manufacturing systems to ensure optimal performance and reliability. Manufacturing systems involve arranging and coordinating machinery, tools, and personnel to efficiently and effectively produce goods. Central to this cluster is the maintenance concept that includes preventive and corrective maintenance strategies. Preventive maintenance implies performance-based or time-based inspection, servicing, or replacement of parts of equipment to eliminate probable surprises, whereas corrective maintenance considers the activity that is performed when a failure occurs in equipment and brings the equipment to its working status (Moubray 1997). This cluster also encompasses the analysis of deadlock –

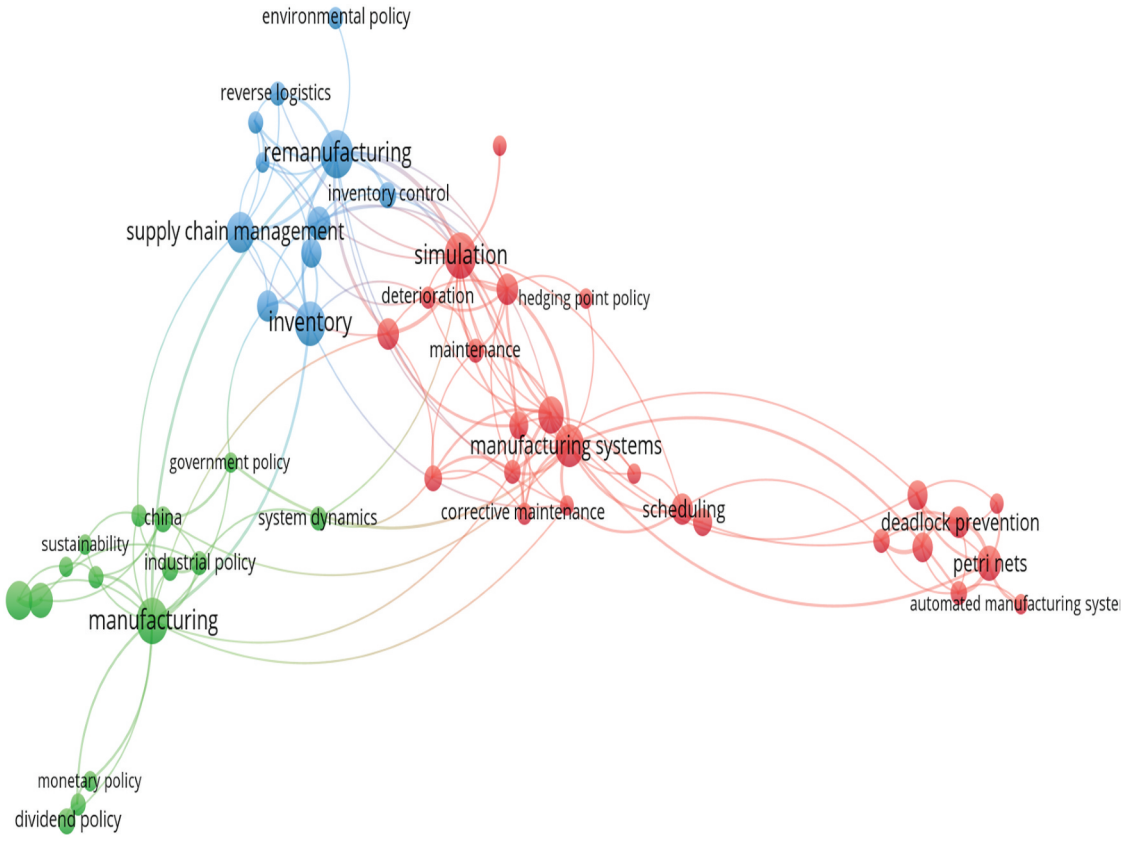

Figure 3. Keyword analysis map.

the situation within some manufactured systems when operations are stuck, as all processes are holding resources that need to be released by each other, and ways to avoid or eliminate it in a system (Coffman et al. 1971). Ageing certain pieces of equipment that may reduce the reliability of the system and computing the maintenance strategy needed for such equipment has also been a major area of concern (Kobbacy and Murthy 2008). Part of this cluster also relies on the use of Petri nets and simulation models in the design and forecasting of systems, which is central to this cluster as these approaches are employed to comprehend and improve the complexity and dynamics (Banks and Steggles 2007; Murata 1989).

The second cluster is '*Industrial Policy and Innovation in Manufacturing*'. This cluster focuses on understanding the relationship between government policy, innovation, and its effect on the manufacturing industry. Industrial policy is defined as the deliberate measures and policies that a government applies to encourage and nurture specific areas, in this case, manufacturing, through subsidies, tariffs, and infrastructure (Rodrik 2008). In particular, the prospect of the readiness of Industry 4.0 technologies: automation, digitalisation, and IoT in particular, is the next level of innovation in production which radically changes the way of printing (Kagermann, Wahlster, and Helbig 2013). Additionally, the absence of innovations can constrain the development and competitiveness of the entire industrial sector, manufacturing. This also encompasses techniques called environmental innovation, wherein processes or technologies that mitigate the adverse effects of the processes in question are employed to achieve sustainability in the production sector. (Rennings 2000). This cluster further connects to the industrial policy of the state by examining how these resources are allocated, and how market players depend on government approval for access. Monetary policies such as interest rates and credit that affect the cost of capital and the level of investment in manufacturing, which are also very important variables in determining the health and profitability of the manufacturing sector (Friedman 1990).

The third cluster mentions '*Sustainable Supply Chain Management and Operations*' which addresses the integration of sustainability principles into supply chain management and operational strategies within manufacturing. Sustainable supply chain management involves the management of materials, information, and finances. As, they move from supplier to manufacturer to wholesaler to retailer to consumer, with a focus on reducing the environmental impact and promoting social responsibility. Closed-loop supply chains are a critical aspect of this, where products are designed and managed such that materials can be reused, remanufactured, or recycled at the end of their life cycle (Guide and Van Wassenhove 2009).

Environmental policies and carbon taxes play a significant role in driving sustainable practices within the supply chain. As, they incentivise companies to reduce their carbon footprints and adhere to environmental regulations (Bovenberg and Goulder 2001). Reverse logistics, which involves moving goods from their typical final destination to capture value or proper disposal, is also a key component of this cluster, contributing to the efficiency and sustainability of the supply

chain. The cluster also explored inventory control and pricing strategies within the context of sustainable operations. For example, implementing proper stock control measures has positive effects on market waste minimisation and resource utilisation efficiency. Finally, one should note that game-theoretic approaches in supply chain management help identify and optimise competitive strategies to increase and sustain business profitability (Cachon and Netessine 2006).

3.3. Theories used in extant literature

The framework under which the reasons for the adoption of government policies in CM can be understood can be classified into several economic and management theories. These theories were gathered by conducting an in-depth content analysis of extant literature on the subject (Table 1). The framework attempts to consider how government policies may promote or restrict the progress of industries through their influence and interaction with other variables such as policies, regulations, industries, and their outcomes.

3.3.1. Economic Regulation Theory

Economic Regulation Theory advocates the use of the government to rectify market imperfections and address social concerns. In the manufacturing industry, this theory posits that government policies and regulations are implemented to cure monopoly, externalities, and information asymmetry. Through market regulation, the state can improve efficiency, ensure consumer protection, and promote competitive conduct (Posner 1974). As for the manufacturing sector, this theory implies that governmental interventions. Such as workplace regulations and building factories in compliance with relevant environmental regulations. However, in its pursuit of a better order, it admits that no regulation or regulation by itself will help if the public suffers from excessive regulations or from regulation of the wrong kind (Stigler 2021).

3.3.2. Public Choice Theory

The unique standpoint of Public Choice Theory contemplates political and economic factors as being responsible for policy formation. In terms of politics, this theory suggests that most government policies are not for economic reasons but due to the preferences of decision-makers, lobbyists, and other available interest groups. In the manufacturing sector, this theory also raises the danger that government controls and policy incentives may be biased. Encouraging specific interest groups or oligopoly friendly industries with powerful lobbyists, which may distort the market. It goes further to state that regulatory capture – intensified by the complexities that allow for the people instigating the regulation to evolve into regulators of that particular industry – helps to dilute the efforts of government participation in the industry (Stigler 2021).

3.3.3. Innovation and Competitiveness Theory

Innovation and Competitiveness Theory proposes that the laws, institutions, and incentives that the state puts in place or provides play an important part in enhancing innovation and competitiveness in the manufacturing sector. Gehl (2020) explains this practice by stating that there has to be prevention against full equity competition with governments aiming at productivity growth, such as R&D tax credits, R&D grants, or technology promotion policies aimed at firms. This especially applies to the manufacturing industry, which is transforming and adapting itself towards new sophisticated manufacturing methods, including automation, artificial intelligence, and the Internet of Things. Manufacturers, in particular, benefit from such government policies because they assist in the acquisition of cutting-edge technology and enhance their productivity and competitiveness.

3.3.4. Industrial Policy Theory

Industrial Policy Theory focuses on government intervention in the improvement of some key sectors, in this case manufacturing. This theory assumes that relying solely on free markets will not always guarantee the most favourable economic outcomes, especially in capital-intensive and long-duration planning sectors (Cohen 2006). Thus, governments use industrial policies to support the development of essential manufacturing sectors, development of supporting facilities, and creation of conducive investment climates. According to this theory, appropriate and relevant industrial policies can enhance the growth of local manufacturing industries, the diversification of economies, and reduce import dependency rates (Bartelme et al. 2019).

3.3.5. Institutional Theory

The emphasis of Institutional Theory is directed towards the role played by institutions, regulatory mechanisms, or

Table 1. Theories discussed in literature.

Theory Name	Definition	Cited Work
Economic Regulation Theory	Advocates government intervention to correct market imperfections, ensure efficiency, and address social concerns.	Posner (1974); Stigler (2021)
Public Choice Theory	Highlights the influence of political and economic factors, suggesting government policies may favor special interest groups, potentially distorting markets.	Stigler (2021)
Innovation and Competitiveness Theory	Emphasizes the role of state-driven laws, institutions, and incentives in fostering innovation and enhancing industry competitiveness.	Gehl and Porter (2020)
Industrial Policy Theory	Focuses on government support for key sectors through strategic interventions like subsidies and infrastructure development to improve economic outcomes.	Cohen (2006); Bartelme et al. (2019)
Institutional Theory	Explores the role of regulatory, legal, and institutional mechanisms in shaping industry practices and fostering compliance.	Amenta and Ramsey (2010); Arranz and Arroyabe (2023)
Resource-Based View (RBV) of the Firm	Suggests that a firm's competitive advantage depends on its internal resources and capabilities, which also affect its ability to benefit from government policies.	Madhani (2010); le Duc and Gammeltoft (2023)

behavioural norms concerning firms and industries. Within this theory, the institutional context determines how manufacturing economic actors behave vis-à-vis policy, legal, and economic constraints (Amenta and Ramsey 2010). For example, property rights, enforcement of contract laws, and organisation of the legal sector, in general, are capable of fostering investments in the manufacturing industry. However, inadequate institutional systems taint not only government interventions but also the functions of institutions (Arranz and Arroyabe 2023).

3.3.6. Resource-Based View (RBV) of the firm

The resource-based view (RBV) of a firm indicates the competitive advantage of an organisational firm's ability to compete based on the internal resources and capabilities of a firm. This theory, in the context of government policies, suggests that, while manufacturing firms can reap the benefits of the government incentives and policies available, they must have the requisite resources and capabilities to do so (Madhani 2010). For instance, firms that excel in management with R&D knowledge and technology are likely to receive more innovation incentives than are those with poor technology and production-oriented firms. Nevertheless, it is worth stressing that not all manufacturing firms within the same economy will emerge in government initiatives in the same way because of variations in internal resources and capabilities relative to healthy industrial performance (le Duc and Gammeltoft 2023).

4. Conceptual framework

Section 2 explains the interrelationships between government intervention (e.g. policy, regulation, and/or incentive) and the emergence, evolution, and growth of circular manufacturing strategies in considerable depth. This framework is based on an in-depth review of extant literature on the subject. It expands on the complex networks of interdependence that exist between these interventions and manufacturing performance by elucidating the various mechanisms, processes, conditions, and variables that lie in this relationship, in addition to the benefits that can be realised through efficient government intervention (Figure 4).

Such regulation serves to enhance the advancement of drugs in an industry governed by policies that are equally under the country's laws. Manufacturing regulations are formulated to boost specific subdivisions of the manufacturing sector. In this case, governments may provide policies such as ending tariffs or taxes on certain goods and suggesting allowable export amounts or construction of roads to ease transportation. This, in turn, affects the dynamics of competition because it enables certain sectors to survive, even if they are provided with pre-launch assistance to help them grow past entry barriers or foreign competition (Lieder and Rashid 2016). Hence, this aligns with industrial and fiscal policies, since any manufacturer such policies dictate capital sources. After considering the location of industries, budgetary decisions, tax regimes and the follow-up expenditures from the government have a major impact on the operability and relevance of manufacturing activities (Genc 2024). In fact, where there is efficient state investment in infrastructure, the expenses incurred in the operations will be lower, and the operations will be more effective. Monetary structures include policies, such as interest rate regimes, conditions under which borrowing is available, and rules that regulate inflation within the manufacturing sector. This results in depressed interest rates and easy credit availability, which stimulate investment in new establishments or further growth of existing establishments, thus enhancing growth in that sector as a whole (Ozili 2024).

Regulations are an important component of this framework. The demand for adherence to regulations regarding pollution prevention, waste disposal, and energy consumption

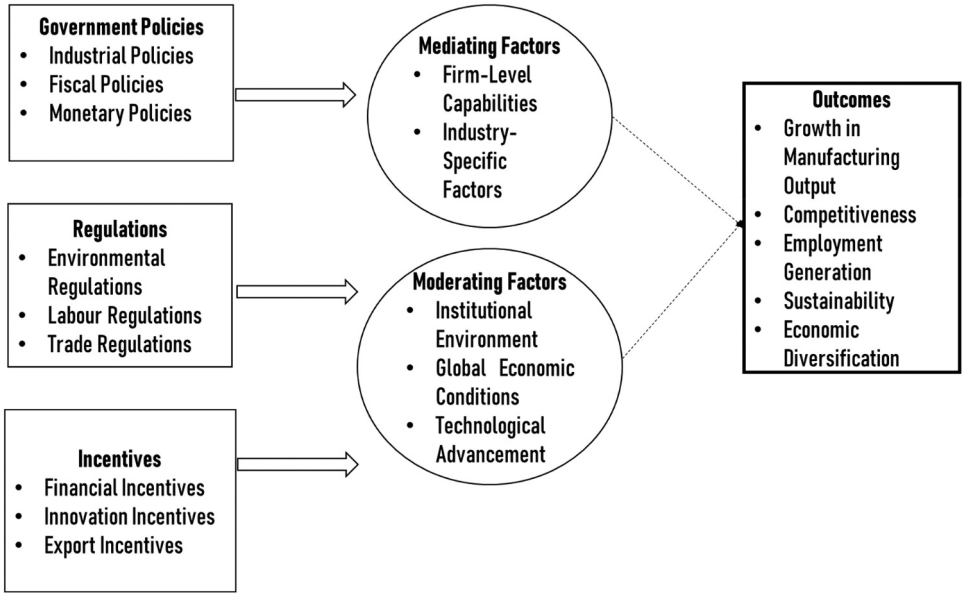

Figure 4. Conceptual framework.

has led to increased cutthroat competition among manufacturers. Although these further increase overheads, they encourage the adoption of environmentally friendly solutions with wider acceptability for the future of the industry (Shang, Song, and Zhao 2022). Similarly, *labour regulations* dictate employment laws, wage levels, and workplace safety guidelines. This ensures fair treatment for workers and a secure working environment, which may lead to increased labour productivity and reduced employee turnover. However, it raises costs and requires effective management practices to remain profitable (Larsson and Lindfred 2019). *Trade regulations* such as restrictions on imports/exports, tariffs, and trade agreements determine market access and competitiveness. They determine how easy it is for firms in the manufacturing sector to reach global markets and access raw materials, thus affecting scalability and international competitiveness (Steinfatt 2020). Further, this framework highlights the role of incentives in stimulating growth in the manufacturing sector.

However, it is vital to understand that certain financing schemes, including grants, tax holidays, and low-cost loans, are very important for appreciably enhancing the level of investment, particularly where the type of investment is labour-intensive manufacturing. In this manner, these incentives help overcome the key barrier to increasing production capacity, particularly through credit financing (Aranda-Usón et al. 2019). Furthermore, globalisation-related innovations have also enabled the use of R&D tax credits and technology adaptation subsidy funding, which serve to accelerate modernisation. This enables innovation possible as it allows manufacturing firms to launch new products, improve their processes, and maintain competitiveness in the global market (Hermundsdottir, Eide, and Aspelund 2021). Finally, subsidies aimed at exporting encourage the growth of industries, as they will support the penetration of other areas. There are many ways through which the state enables producers to export more; for example, customs and policy solutions such as subsidies for exports or preferential agreements, thereby increasing total and effective exports (Rishanty, Sambodo, and Wicaksono 2022).

A few multilevel and industry characteristics influence the moderation of the government's impacts on the economy. The extent of adjustment to government measures is subject to the company's ability. Natural factors, such as the availability of funds, people, and technology, are crucial components in the actualisation of policies and effective implementation of incentive programmes available to the government. Companies with relative resource endowments are more likely to be legal, techno-savvy, and expand their scope of operation (Asif and Farazee 2017). This organisational structure also helps to mediate this effect owing to its managerial capacity structures, which maximise compliance with regulations and effectively utilise the incentives provided by the government. They also fuel innovation and promote incremental change, which is required for growth in the competitive landscape (Beducci et al. 2024). An enterprise's innovation potential is understood as incorporating and implementing changes associated with modifications in managerial processes or production technology in response to the measures of public authorities (Saari et al. 2024).

At the industry level, it is common to note the influence of sectoral characteristics on the results of government actions. Different manufacturing subsectors encounter various levels of capital intensity, amount of required labour, and employment of technologies, which in turn affect the implemented policy measures and incentives (Horbach and Rammer 2020). For example, financial incentives may be offered to the capital-intensive sector, and the labour-centric sector may be more prone to labour regulations. Supply chain integration also exerts influence at the industry level because it determines how responsive industries are to trade or related industrial policies. Compared to firms with low supply chain connections, firms that are integrated and connected are able to adapt to either internal or external changes whenever trade regulations change (Di Maria, De Marchi, and Galeazzo 2022). Factors that ought to be considered here include the competitive environment, changing demand, and market access conditions, among others, that operate within the market and act as mediators between government intervention and the sectoral growth change rate. Since companies operate in very competitive environments, every organisation must engage in innovations and improvements to their practices, as there is no alternative to backing policies and programmes that are geared towards the above ends (Papachristos 2014).

This framework and its variables also contribute to intervention outcomes. It is in this respect that the quality of regulations is the most critical separately considered moderating variable. When properly enforced, reasonable and unambiguous policies can produce desired outcomes. On the contrary, weakly enforced regulations will render very sound policies, regardless of how well they are developed (Gusmerotti et al. 2019). The institutional environment is another crucial moderating factor, and political stability plays a vital role. A stable political environment provides foresight and assurance in making choices that will have implications in the future. Instead, political instability is a source of risk and, therefore, discourages investment and the slow growth of the sector (Mishra et al. 2019).

Moreover, the level of corruption in public institutions affects the anticipated success of curtailing the negative externalities. When corruption is rife, the efficiency of measures deteriorates owing to resource wastage, which increases the cost of compliance by entrepreneurs, hence stunting growth within the manufacturing industry (Zhou and Li 2021). The external situation within the world economy contains elements that define how far government policies are towards expansion of the economy via export strategies or the building up of domestic production. It is a trend in the global market that will determine the performance of export incentives and trade restrictions as they pertain to variations in demand and economic cycles. For instance, the downward pressure from a global recession on the demand for products, such that the use of export subsidies on finished goods may become inefficacious.

Foreign direct investments (FDI) are another important factor that facilitates regulatory processes. Global economic situations and local incentives influence FDI inflows, which can significantly impact the growth of the manufacturing industry. High levels of FDI can bring capital and the skills necessary for expansion, while low levels may hinder growth.

The final moderating factor identified in the framework was technological advancement. *Policy support and incentives* determine the rate at which technology is assimilated into the manufacturing sector. Therefore, governments that encourage technology adoption and digitalisation would help their manufacturing sectors retain their competitive edge in the global market. *Digitalisation* is indispensable in the manufacturing sector. The promotion of sectoral growth and competitiveness can be significantly facilitated by government support for Industry 4.0 initiatives, which are designed to integrate digital technologies into manufacturing processes (Neligan et al. 2023).

Several prospective *outcomes* will be realised as a result of the effective implementation of policies by governments, regulations, and incentives as per the framework. The first is the expansion of manufacturing output, which involves an increase in production volume and value added within the sector. This increase is the result of policies and incentives that increase efficiency, reduce operational costs, and encourage investments. An additional significant outcome is the increase in *competitiveness*. Global competition presents opportunities for manufacturing firms owing to policy initiatives that seek to boost such firms by way of improved productivity and market access, both within and outside the country. Increased competition translates into continuous improvement and growth in market share (Popović, Ivanović-Djukić, and Milijić 2022). However, it is not surprising that employment generation follows growth in this sector. An increase in production or the opening up of new manufacturing units by a firm creates jobs, which leads to positive economic changes. This process is important in many developing countries where industrialisation continues to be a major employer (Dewi and Pratama 2021). In addition, sustainability is bent in extreme measures of environmental protection and encouraging green technologies. There are ways in which government policies can help the sector be environmentally friendly, contributing to ecological stability through carbon reduction (Bjørnbet and Vildåsen 2021). Finally, thanks to the developed manufacturing industries in the country, there is economic diversification. In contrast, the state is through monopolistic vulnerability by focusing on a few infrastructural industries. This will cushion shocks and expand growth opportunities in the long term (Chen, Shen, and Zheng 2024).

5. Future research agenda

Several key areas for future research emerge, based on co-word analysis and the theoretical and conceptual frameworks discussed. These areas aim to enhance the integrated knowledge of the complex relationships between government policies, regulations, and incentives, and their regard to the manufacturing sector. The proposed areas of the research agenda include but are not limited to the following.

5.1. Adoption of predictive maintenance technologies in circular manufacturing

Government policies play a crucial role in fostering the adoption of predictive maintenance technologies in circular manufacturing systems. Through incentives, such as tax benefits and grants, governments can alleviate the financial burden of integrating advanced technologies (Hopp & Spearman, 2011). Additionally, regulatory frameworks mandating predictive maintenance standards can drive widespread adoption, ensure system reliability, and minimise environmental impact. These policy-driven approaches can significantly enhance the effectiveness of predictive maintenance for the broader goals of circular manufacturing.

5.2. Impact of industry 4.0 on the adoption of circular manufacturing policies

Future research should examine the assessment of the impact of different Industry 4.0, and will also include their effectiveness and implementation by the government. Particularly policies directed towards the implementation of circularity, including the crucial circles of manufacturing strategy. These technologies have transformed manufacturing, thus calling for a reassessment of how industrial policy can enhance and harness technology to foster circularity (Kagermann, Wahlster & Helbig, 2013). It is crucial to understand this interaction to formulate policies that encourage innovations compatible with evolution in the circular economy while ensuring sustainability and competitiveness in a fast-paced technology-oriented world.

5.3. Effectiveness of government policies in promoting closed-loop supply chains

An additional aspect worthy of future investigation is the role of government policies in supporting the actual practice of closed-loop supply chains in various manufacturing industries. To decrease environmental footprints and facilitate circularity in manufacturing processes, closed-loop supply chains must be constructed to focus on the turnover, remanufacturing, and recycling of projected materials only (Guide & Van Wassenhove, 2009). How other limitations increase lending exploration should be astute about how government interventions can seek resolution to these barriers and enhance the benefits of closed-loop systems?

5.4. Impact of institutional quality on the adoption of circular manufacturing policies

As another direction, research should explore tendencies across institutions that affect the use and success of government policies that promote circular manufacturing. According to, Institutional Theory strong legal and regulatory systems are imperative for policies to be effective (North, 1990) according to the Institutional Theory. Studies should examine how circular economy principles are being implemented, regulation compliance, improvement potential, and promotion of policies on the competitive advantages of circular manufacturing strategies using varying levels of institutional strength and governance.

6. Conclusion, implications and limitations

This review highlights the adoption of government policies, regulations, and incentives for implementing circular

manufacturing strategies. The findings reveal that while robust national innovation systems supported by well-crafted measures. The strategic plans can significantly enhance innovation, competitiveness, and growth in the sector, inadequate regulatory frameworks or poorly executed strategies can hinder progress. There is a flow of objectives of the government and requirements of the industry; thus, strategies for an effective manufacturing environment need to be integrated. This review highlights the necessity of examining these policies and regulations and their effects on the industry, stressing that policies must be assessed and reviewed constantly to help deal with new and existing problems.

The conceptual framework focuses on the determinants of policies and the regulatory framework of different governments regarding the' development 'of the manufacturing sector. Nevertheless, the provision of such services did not meet expectations. Appropriate policy measures that address the true situation in the industry support positive transformation. This review also draws attention to the need for a policy that focuses on the particular nature of the economy and society in each country.

This study emphasises the importance of government policies, regulations, and incentives as the key determinants of growth in the manufacturing sector. Governments play a critical role in creating an enabling environment for circular manufacturing by enacting waste reduction laws and promoting mandatory recycling/reuse quotas. Promote public awareness campaigns to shift consumer preferences towards sustainable products. Educate manufacturers about the long-term benefits and implementation strategies for circular manufacturing. Corporate leaders and industry bodies are responsible for operationalising circular manufacturing within sectors by implementing closed-loop supply chains to recover and recycle resources. Advanced tools, such as AI, IoT, and blockchain, are used to track, optimise, and enhance circular manufacturing systems. The findings underline the necessity for the industry to participate in policy-making and policy development processes, and to guarantee that the rules and guides meet their needs as intended. Governments should engage industry leaders during policy formation to ensure that the regulations are both practical and impactful. Regular forums or platforms should be established in which stakeholders can discuss progress, share challenges, and propose solutions. Finally, the review notes the advantages associated with the application of the new development and digital technologies termed Industry 4.0, which would add efficiency and competitive advantage to operations in the global market.

Despite its comprehensive approach, this study had several limitations. The scope of the literature considered may not fully capture all relevant studies, particularly those from emerging economies or less-accessible sources. This includes an evaluation for use in the amalgamation of the results of such an analysis. Thus, the review examines policies and regulations and their immediate effects on manufacturing and growth prospects. This includes adjusting the principles and techniques of studying the gathered data according to the specificities of time. Policies and practices should target these limitations by bringing up new data and designing how, when, and at what intervals the policies and specific sectors will be assessed.

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Author's contribution statement

1. Dr. Kiran Nair: Writing – original draft, Methodology
2. Seema Bhardwaj: Writing – original draft, Visualisation, Data curation.
3. Ritika Chopra: Original Draft and Formal analysis
4. Sreejith Balasubramanian: Supervision
5. Mahima Misra: Writing – Proof-reading

All authors have read and approved the final version of the manuscript.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [Seema Bhardwaj], upon reasonable request".

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