

The Role of Behavioural and Environmental Economics in Sustainable Manufacturing

Rashmeet Kaur^(✉), John Patsavellas, and Konstantinos Salonitis

SMSC, Cranfield University, Bedford MK430AL, UK
rashmeet.kaur@cranfield.ac.uk

Abstract. Sustainable manufacturing is a rapidly growing field that primarily seeks to reduce the environmental impact of manufacturing processes. Although the three-lens approach of social, environmental, and economic aspects remain the primary focus in any sustainability study, the domains of behavioral, and environmental economics along with smart data technologies have not been used in a unified approach. Through a review of the state of the art, this paper establishes the individual cases for each one of these domains and underscores the research interest in their combinatorial application and possible complementary efficacy for advancing the development of sustainable manufacturing strategies. A research agenda involving comparative testing and the development of pertinent policies and interventions for sustainable manufacturing is proposed for the integration of behavioral economics and environmental economics, within the context of sustainable manufacturing.

Keywords: Sustainable Manufacturing · Behavioral Economics · Environmental Economics

1 Introduction

As the global manufacturing sector grapples with the challenge of advancing sustainable production, it has increasingly become desirable to identify suitable transformational approaches and tools that can comprehensively address all the dimensions of sustainability and facilitate a seamless transition towards a more sustainable future. One such transformational approach could be the deployment of behavioral economics (BE), which combines insights from psychology and economics to comprehend, predict, and influence the behavior of individuals and organizations towards more sustainable practices and outcomes. Similarly, environmental economics (EE) could offer a transformational approach through the systematic assessment of the economic ramifications of the environmental impact of contemporary manufacturing practices along with the costs and benefits of any improvement strategies aimed at reducing carbon emissions. This is depicted in Fig. 1.

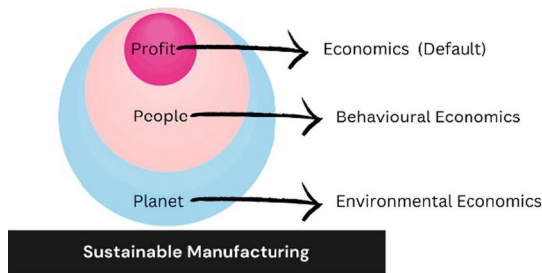


Fig. 1. Three Lens view of Sustainable Manufacturing

2 Behavioral Economics and Sustainable Manufacturing

Over the last few decades, the genre of BE has been developed and deployed through credible research methods to identify empirical laws that can accurately describe and influence human behavior when the neoclassical economics assumptions of linear cause-and-effect factors in human behavior around customer satisfaction and producer profit prove inadequate or invalid [1, 2]. It has also been used to investigate the implications of deviations from neoclassical human behavior assumptions for the functioning of broader economic systems, institutions, and public policy [3, 4]. It seeks to provide empirical evidence about the structure and content of the economics utility function, or any construct that may replace it, in a valid behavioral theory to enhance the accuracy of predictions about human economic behavior [5, 6].

The keyword combination phrase of “Behavioral economics” was used to search for relevant literature on three large academic databases: Scopus, Web of Science, and IEEE Xplore, with an open time filter to capture the maximum number of works. Initial title-filtering to identify and exclude duplicates was carried out both horizontally and vertically, i.e., within each database and across all three. Further screening of papers was done by title and abstract content, to classify them into industry-sector relevance groupings. A systematic literature analysis of this domain of knowledge as it relates specifically to the manufacturing sector (using the PRISMA statement [7]) yielded 16 research papers as shown in Fig. 2.



Fig. 2. PRISMA statement summary for BE

The taxonomy of research endeavors across the spectrum of human activity, as depicted in Fig. 3, aptly demonstrates a substantial body of scholarly work in the realm of BE. There is a category labelled as agnostic in Fig. 3, which covers a broad range of concepts, theories and tools that constitute the BE toolkit and are not about the implementation of BE toolkit in different sectors.

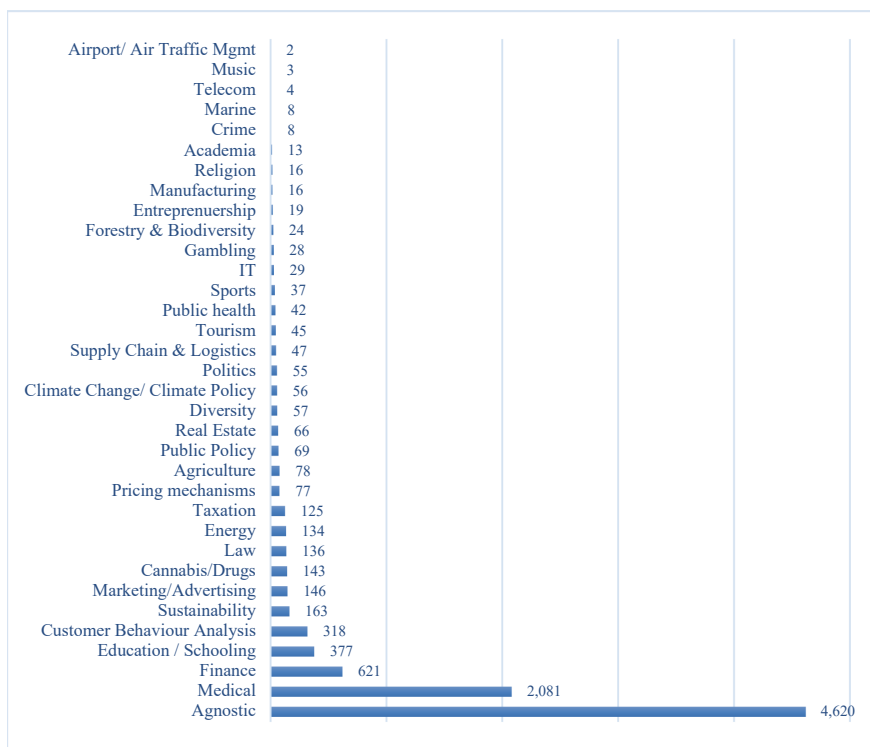


Fig. 3. Industry wise use of BE

Among the various sectors represented, the medical and healthcare domains emerge as the primary areas of focus, showcasing the highest prevalence of implementation and utilization of BE principles. Following suit, the field of finance exhibits a noteworthy presence in terms of adoption and practical application of behavioural economics concepts. However, full text analysis of the 16 papers referencing manufacturing in their titles revealed that only 1 paper demonstrates using applying a BE theory for optimisation of their predictive maintenance optimisation [8]. The themes represented in the remaining 15 papers are focused on human-robot collaboration and the impact of technology on human decision-making processes along with behaviourally informed financial decision making and pricing strategies. Evidently, the findings suggest a dearth of research work utilizing BE in the various aspects of manufacturing. Notably, substantial research gaps exist in important domains such as end-to-end supply chain management, integrated manufacturing systems, as well as the emerging realm of digital manufacturing, among others that could warrant further investigation. Only the sub-set of prospect theory which suggests that people tend to be risk-averse when it comes to potential gains but risk-seeking when facing potential losses has been used in the context of predictive maintenance for risk assessment [8] whilst other popular BE theories such as rational choice theory, libertarian paternalism, and choice architecture, have yet to be examined in the context of manufacturing. The absence of research on the application of these

theories presents a notable gap in knowledge that warrants attention, specifically within the context of sustainable manufacturing systems.

3 Environmental Economics and Sustainable Manufacturing

Environmental economists use a variety of methods to study the environment, including cost-benefit analysis, environmental impact assessment, and natural resource economics [9, 10]. EE has grown rapidly in recent years due in part to the increasing awareness of environmental problems, such as climate change, pollution, and resource depletion [10, 11]. Developing policies and solutions that can help to address these problems is the perpetual target of economists in this field [12, 13]. An additional systematic literature review was conducted to identify the combined use of EE and BE specifically in manufacturing. The outcomes of the PRISMA literature analysis of the entire literature pool with no time filter using the results of keyword for search “environmental economics” are summarized in Fig. 4.



Fig. 4. PRISMA statement summary for EE

Figure 5 shows the top-20 themes from a detailed thematic analysis of the diverse areas of research focus within EE. A total of 197 papers were identified to be directly or indirectly associated with manufacturing. However, a detailed analysis of these papers clearly reveals that there is no research work combining BE and EE in the context of manufacturing or sustainable manufacturing.

While the combination of BE and EE has been explored in relation to sustainability from a consumer perspective, based on this analysis there is an absence of work with regards to human decision-making models that relate to adopting sustainable practices in manufacturing organizations. This offers an opportunity to examine the potential of BE in combination with environmental costing, sustainable performance measurement and economic analysis for better outcomes in the drive for sustainable transformation of manufacturing.

4 Discussion

The combination of BE and EE within the realm of sustainable manufacturing refers to the converging interaction of these two disciplines towards advancing sustainable outcomes in manufacturing organizations. It acknowledges that addressing sustainability challenges in manufacturing necessitates an understanding of both human behavior and the environmental impacts of industrial activities. BE focuses on analyzing the

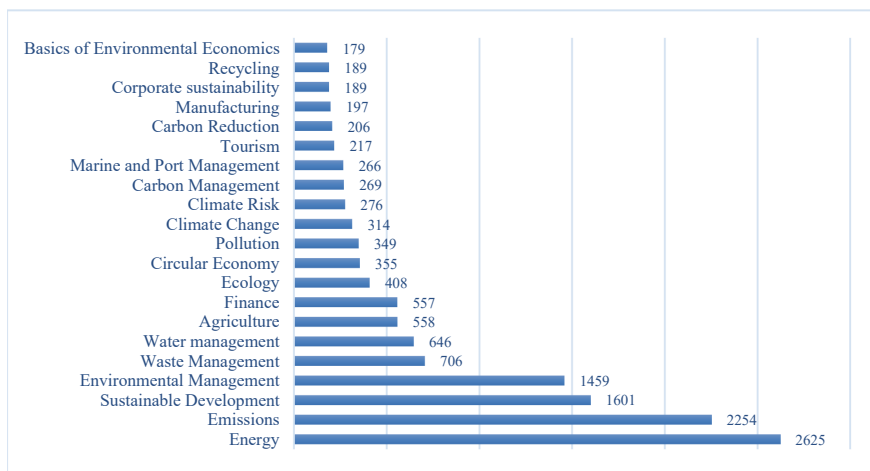


Fig. 5. Top 20 themes in EE literature

decision-making and actions of individuals and organizations within economic contexts, acknowledging that human behavior is not always rational or solely driven by economic considerations. In the context of sustainable manufacturing, the theories of behavioral economics can aid in identifying and comprehending the factors that influence decision-making processes related to environmental sustainability. This may encompass studying how individuals or organizations perceive and respond to environmental risks, how they prioritize sustainability in their decision-making, and which behavioral interventions can be employed to foster and even “nudge” manufacturing professional towards more sustainable practices. The main tools, concepts, and theories from the BE body of knowledge that could be critically examined for this purpose are rational choice theory, anchoring, prospect theory, loss aversion, status quo bias, mental accounting, framing, choice architecture, reciprocity, nudging and libertarian paternalism [3, 14–16]. Given the use of EE for investigating the economic consequences of environmental policies, regulations, and resource utilization and its utility in quantifying the costs and benefits associated with environmental degradation and sustainability measures, its application in the manufacturing sector is of legitimate interest. Most importantly, EE can help with the setting of net zero goals in the manufacturing sector and providing useful key performance indicators that are could be used to track sustainable transformation. To assess the current state of sustainable manufacturing transformation, it is important to examine the progress made towards established net zero goals and targets. Key performance indicators from environmental economics literature can provide insights into how the sector is performing against defined sustainability objectives. However, achieving these targets also requires comprehending behavioral factors. Previous research shows BE has been effectively utilized in sectors like healthcare and finance to positively influence behaviors. Identifying examples where behavioral techniques have been successfully deployed in manufacturing could illuminate possibilities for wider adoption across the sector. Analyzing which specific components of sustainable manufacturing strategies

are most amenable to behavioral interventions could further guide integration. Overcoming barriers to sustainability transformation relies on aligning economic incentives and behavioral motivations. EE can quantify the costs and benefits of various policy options, while behavioral analysis provides understanding of how to effectively motivate change. Harnessing insights from both disciplines could facilitate more impactful and scalable progress towards sustainable manufacturing.

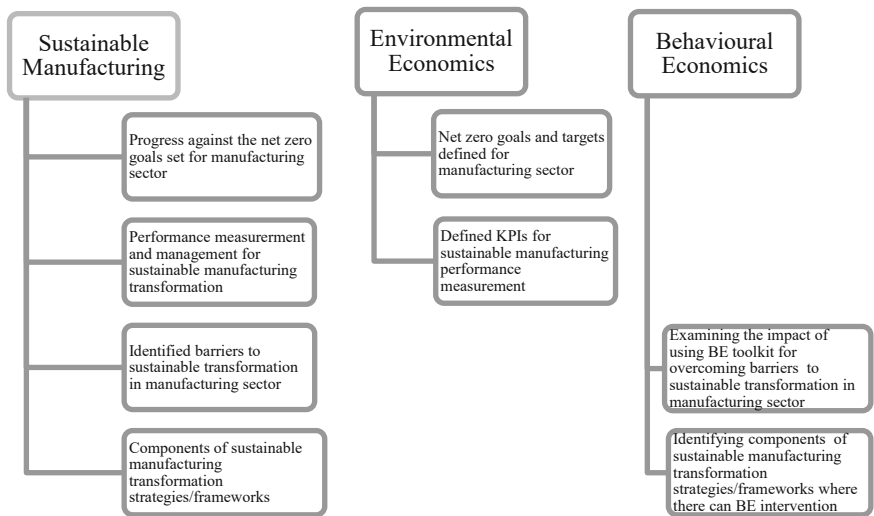


Fig. 6. Proposed research direction

In summary, a research direction as shown in Fig. 6, focused on integrating BE and EE has potential to advance sustainable manufacturing. Key priorities include cataloguing examples of BE deployment in manufacturing much like the concepts of established research like behavioural safety or behavioural operation management, determining high-impact integration points, and co-developing solutions that synthesize economic and behavioural insights. The overall research questions that could be covered in the future research agenda are listed below in Table 1. More empirical research blending theory and practice will be essential to realizing the benefits of this multidisciplinary approach.

By identifying the most suitable BE tools that could influence behavioural change and decision making and integrating them with key sustainable performance measurement parameters from EE analysis, the combinatorial impact on manufacturing sustainability may be critically investigated. Consequently, it is necessary to assess and measure the outcomes of such combination through a suitable performance management system and establish a guiding framework for facilitating the transition towards more advanced sustainable manufacturing practices.

Table 1. Research questions for interdisciplinary future research agenda

Sustainable Manufacturing	Environmental Economics	Behavioural Economics
What is the progress of sustainable manufacturing transformation in set net zero goals and targets?	What specific net zero goals and targets have been set for manufacturing sector?	Which industries or sectors have utilised BE tools and how may have these enhanced their performance?
How is the performance of sustainable manufacturing transformation measured currently against the defined targets?	What are the key performance indicators defined in EE literature specifically for manufacturing and sustainable manufacturing transformation?	Are there any use cases of BE being deployed within manufacturing?
What barriers is the manufacturing sector facing in sustainable transformation?		Can BE toolkit be harnessed to facilitate a more widespread adoption of sustainable manufacturing?
What strategies or frameworks are most frequently used for sustainable manufacturing transformation?		What specific areas or components of sustainable manufacturing strategies can BE techniques be introduced more effectively in?

5 Conclusion

A systematic review of the state of the art reveals a lack of existing research on the individual and combined contributions of BE and EE in sustainable manufacturing. The proposed research agenda provides potential directions for future studies to investigate the integration of insights from these two domains to advance sustainable manufacturing practices. Bridging theory with practice, the converging perspective of BE and EE could allow for a more comprehensive understanding of human decision-making, economic incentives, and environmental outcomes. This could pave the way for a novel, approach towards the green and clean transformation of the manufacturing sector. Empirical research will be key to assessing the promise of such a cross-disciplinary approach.

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