

## LEAN AND AGILE PRODUCTION FOR SUSTAINABILITY PERFORMANCE IN MEDIUM AND LARGE MANUFACTURING FIRMS IN SAUDI ARABIA

### PRODUÇÃO ENXUTA E ÁGIL PARA O DESEMPENHO EM SUSTENTABILIDADE EM MÉDIAS E GRANDES EMPRESAS DE MANUFATURA NA ARÁBIA SAUDITA

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#### Abstract

Manufacturing firms are increasingly pressured to achieve sustainability performance while responding to dynamic and complex business environments. Lean production and agile production have been widely adopted as operational strategies that can potentially enhance sustainability outcomes. However, empirical research examining the combined influence of these production approaches and the role of supply chain collaboration remains limited. This study investigates the relationships between lean production, agile production, and sustainability performance, considering economic, environmental, and social dimensions as distinct constructs. It also examines the moderating role of supply chain collaboration. Data were collected from medium and large manufacturing firms in the Kingdom of Saudi Arabia through an online survey, yielding 181 valid responses. Structural equation modelling (SEM) was employed to test the proposed relationships. The results indicate that lean production positively influences economic, environmental, and social sustainability performance, while agile production demonstrates weaker direct effects when both approaches are examined simultaneously. Supply chain collaboration positively moderates the relationship between lean production and economic sustainability but negatively moderates the relationships between agile production and the sustainability dimensions. These findings contribute to the literature on sustainable manufacturing and provide managerial insights into the strategic use of lean

#### Resumo

As empresas do setor manufatureiro estão cada vez mais pressionadas a alcançar um desempenho sustentável, ao mesmo tempo em que respondem a ambientes de negócios dinâmicos e complexos. A produção enxuta e a produção ágil têm sido amplamente adotadas como estratégias operacionais com potencial para melhorar os resultados de sustentabilidade. No entanto, as pesquisas empíricas que examinam a influência combinada dessas abordagens de produção e o papel da colaboração na cadeia de suprimentos ainda são limitadas. Este estudo investiga as relações entre produção enxuta, produção ágil e desempenho em sustentabilidade, considerando as dimensões econômica, ambiental e social como constructos distintos. Ele também examina o papel moderador da colaboração na cadeia de suprimentos. Os dados foram coletados de empresas de manufatura de médio e grande porte no Reino da Arábia Saudita por meio de uma pesquisa online, resultando em 181 respostas válidas. A modelagem de equações estruturais (SEM) foi empregada para testar as relações propostas. Os resultados indicam que a produção enxuta influencia positivamente o desempenho em sustentabilidade econômica, ambiental e social, enquanto a produção ágil demonstra efeitos diretos mais fracos quando ambas as abordagens são examinadas simultaneamente. A colaboração na cadeia de suprimentos modera positivamente a relação entre a produção enxuta e a sustentabilidade econômica, mas modera negativamente as relações entre a produção ágil e as dimensões da sustentabilidade. Essas descobertas



and agile production in enhancing sustainability performance.

**Keywords:** Agile Production. Lean Production. Manufacturing Sustainability. Supply Chain Collaboration. Sustainability Performance.

*contribuem para a literatura sobre manufatura sustentável e fornecem insights gerenciais sobre o uso estratégico da produção enxuta e ágil para melhorar o desempenho em sustentabilidade.*

**Palavras-chave:** *Produção Ágil. Produção Enxuta. Sustentabilidade na Manufatura. Colaboração na Cadeia de Suprimentos. Desempenho em Sustentabilidade.*

## 1 INTRODUCTION

Sustainability has become a critical concern for manufacturing firms operating in increasingly complex and dynamic environments. Organisations are under growing pressure from governments, customers, and other stakeholders to improve their economic performance while simultaneously addressing environmental and social responsibilities (Janmontree & Zadek, 2020).

Manufacturing firms face challenges arising from globalization, rapid technological change, and rising environmental awareness (Teixeira *et al.*, 2021; Orji & Liu, 2020). Operational strategies such as lean production and agile production have therefore gained increasing attention as mechanisms for improving competitiveness and operational performance.

Lean production focuses on eliminating waste and improving efficiency within manufacturing systems (Womack *et al.*, 1990; Shah & Ward, 2003). Agile production, in contrast, emphasizes flexibility and responsiveness to changing market conditions (Goldman *et al.*, 1995).

Despite their potential benefits, empirical findings regarding the influence of lean and agile production on sustainability performance remain inconsistent (Martínez-Jurado & Moyano-Fuentes, 2014). Moreover, relatively little research has examined the combined effects of these production approaches and the moderating role of supply chain collaboration.

This study addresses this gap by examining the relationships between lean production, agile production, and sustainability performance across three dimensions: economic, environmental, and social sustainability.

## 2 LITERATURE REVIEW

### 2.1 Lean production

Lean production is widely regarded as a management philosophy aimed at minimizing waste while maximizing customer value (Womack & Jones, 1996). It emphasizes continuous improvement, efficient resource utilization, and streamlined production processes.

Previous research indicates that lean practices such as just-in-time production, total productive maintenance, and value stream mapping can improve operational efficiency and reduce waste (Hopp & Spearman, 2004). These practices contribute to improved productivity and quality performance.

From a sustainability perspective, lean production has been associated with reduced resource consumption, improved operational efficiency, and enhanced environmental performance (Inman & Green, 2018).

Lean production aims to eliminate waste and enhance operational efficiency through continuous improvement (Womack & Jones, 1996).

**Table 1**  
*Selected definitions of lean production*

Author	Definition
Womack <i>et al.</i> (1990)	Lean production focuses on reducing waste and minimizing production costs.
Womack & Jones (1996)	Lean thinking emphasizes value, value stream, flow, pull and perfection.
Shah & Ward (2003)	Lean production integrates management practices such as JIT, quality systems and supplier management.
Bhasin (2015)	Lean production is a systematic approach to eliminate waste through continuous improvement.

Lean practices such as just-in-time production and total productive maintenance contribute to improved efficiency and reduced waste generation (Hopp & Spearman, 2004).

## 2.2 Agile production

Agile production refers to the capability of manufacturing firms to respond quickly and effectively to rapidly changing market conditions (Goldman *et al.*, 1995). Agile manufacturing emphasizes flexibility, innovation, and the ability to adapt production systems to changing customer demands.

Agile production enables firms to respond to market uncertainty while maintaining competitiveness in dynamic environments (Gunasekaran *et al.*, 2018).

Although agile production enhances flexibility and responsiveness, its impact on sustainability performance remains an area requiring further empirical investigation.

## 2.3 Sustainability performance

Sustainability performance is commonly conceptualized using the triple-bottom-line framework, which includes economic, environmental, and social dimensions (Carter & Rogers, 2008).

Economic sustainability refers to financial performance and long-term profitability. Environmental sustainability focuses on reducing environmental impacts such as waste and emissions. Social sustainability relates to employee welfare, workplace safety, and community well-being (Sarkis, 2010).

Previous research has often examined sustainability as a single construct rather than analysing its individual dimensions separately (Ruiz-Benitez *et al.*, 2019). Examining these dimensions individually provides a clearer understanding of sustainability performance outcomes.

## 2.4 Supply chain collaboration

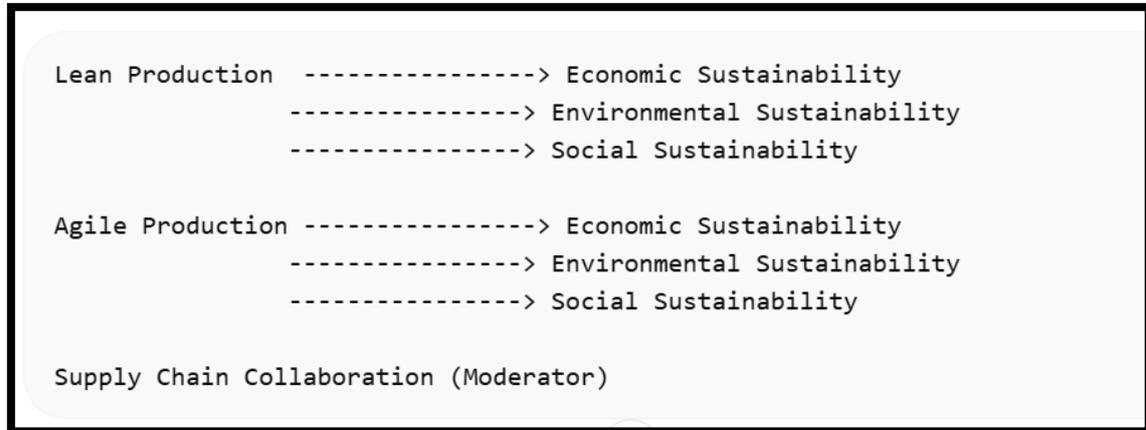
Supply chain collaboration involves cooperative relationships between organizations within a supply chain aimed at improving operational performance (Cao & Zhang, 2011).

Collaborative supply chain relationships enable firms to share information, coordinate activities, and manage risks more effectively (Min *et al.*, 2005). These

collaborative mechanisms may influence the effectiveness of production strategies such as lean and agile manufacturing.

### Figure 1

*Conceptual framework of the study*



The figure illustrates the theoretical model examining the relationships between lean production and agile production and the three dimensions of sustainability performance (economic, environmental and social). It also shows the moderating role of supply chain collaboration in influencing these relationships within manufacturing firms. Source: developed by the author based on the research model.

## 3 RESEARCH METHODOLOGY

This study adopts a quantitative research design to examine the relationships between lean production, agile production, supply chain collaboration, and sustainability performance.

Data were collected through an online survey distributed to medium and large manufacturing firms in the Kingdom of Saudi Arabia. A total of 700 firms were contacted, and 181 valid responses were obtained.

The constructs were measured using established measurement scales from previous research. Structural equation modelling (SEM) was used to test the hypothesized relationships between the variables.

This study adopts a **quantitative research design**.

**Table 2**

*Constructs used in the research model*

<b>Construct</b>	<b>Description</b>
Lean Production	Waste reduction and operational efficiency practices
Agile Production	Flexibility and responsiveness to market demand
Supply Chain Collaboration	Cooperation between suppliers and customers
Economic Sustainability	Financial performance and competitiveness
Environmental Sustainability	Environmental protection and resource efficiency
Social Sustainability	Employee welfare and social responsibility

Data were collected from **medium and large manufacturing firms in Saudi Arabia** through an online survey. A total of **700 firms were contacted**, resulting in **181 valid responses**. Structural equation modelling was used to analyse the relationships between the constructs.

## 4 RESULTS

The results show that lean production significantly influences economic, environmental, and social sustainability performance. When lean and agile production were analysed simultaneously, lean production emerged as the dominant predictor of sustainability performance.

Agile production showed weaker direct effects when both production approaches were included in the model. However, when analysed independently, both lean and agile production demonstrated positive relationships with sustainability performance.

Supply chain collaboration was found to moderate the relationships between production strategies and sustainability outcomes. It positively moderates the relationship between lean production and economic sustainability performance but negatively moderates the relationships between agile production and sustainability performance dimensions.

**Table 3***Profile of survey respondents*

Category	Percentage
Operations managers	32%
Production managers	28%
Supply chain managers	25%
Senior executives	15%

**Figure 2***Structural Equation Model Results*

The figure presents the structural equation model used to analyse the relationships between lean production, agile production and sustainability performance. The model highlights the significant paths identified in the empirical analysis and illustrates the moderating influence of supply chain collaboration on the relationships between production strategies and sustainability performance dimensions. Source: empirical results of the study.

**Table 4***Summary of hypothesis testing results*

Hypothesis	Relationship	Result
H1	Lean production → Economic sustainability	Supported
H2	Lean production → Environmental sustainability	Supported
H3	Lean production → Social sustainability	Supported
H4	Agile production → Economic sustainability	Supported
H5	Agile production → Environmental sustainability	Supported
H6	Agile production → Social sustainability	Supported

The results show that **lean production has a stronger influence on sustainability performance compared with agile production.**

## 5 DISCUSSION

The findings indicate that lean production plays a significant role in improving sustainability performance in manufacturing firms. Lean practices reduce waste, enhance resource efficiency and improve operational performance.

Agile production contributes to flexibility and responsiveness but demonstrates weaker direct effects on sustainability outcomes when both production strategies are examined simultaneously.

Supply chain collaboration influences the effectiveness of these production strategies by facilitating coordination and information sharing between supply chain partners.

## 6 CONCLUSION

This study examined the relationships between lean production, agile production, supply chain collaboration, and sustainability performance in manufacturing firms.

The results demonstrate that lean production plays a dominant role in enhancing sustainability performance, while agile production contributes more modestly to sustainability outcomes.

Supply chain collaboration influences the relationships between production strategies and sustainability performance, highlighting the importance of collaborative supply chain practices.

These findings provide practical insights for manufacturing managers seeking to improve sustainability performance through operational strategies and supply chain collaboration.

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### **Authors' Contribution**

All authors contributed equally to the development of this article.

### **Data availability**

All datasets relevant to this study's findings are fully available within the article.

### **How to cite this article (APA)**

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