**Master's thesis**

MSc Supply Chain Management

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# The Effect of Inventory Leanness on Environmental Performance: the Moderating Role of Competition

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## Abstract

### Purpose

The purpose of this study was to examine the underexplored relationship between inventory leanness and environmental performance. Additionally, industry competition was tested as potential moderator.

### Design/methodology/approach

This study used a quantitative approach to investigate the relationship between inventory leanness, environmental performance and industry competition. For this, data from 2017 to 2022 was collected from Compustat and Refinitiv, after which regression analyses were performed. The sample consisted of 3108 observations across 518 US manufacturing firms.

### Findings

This study found a positive association between inventory leanness and environmental performance, demonstrating that firms with lower inventory levels exhibit greater environmental performance. Several robustness checks led to the same conclusion. The moderating effect of industry competition was found to be non-significant.

### Originality/value

This study adds to the limited empirical literature examining the relationship between inventory leanness and environmental performance for US manufacturing firms, using secondary data. This study also contributed to the inventory leanness – environmental performance relationship by testing a potential moderator, which has been overlooked in most previous studies.

**Keywords:** Inventory management, Inventory leanness, Environmental performance, Manufacturing industry, Competition

**List of abbreviations**

| | |
|---|---|
| ELI | Empirical Leanness Indicator |
| ESG | Environmental Social & Governance |
| HHI | Herfindahl-Hirschman Index |
| JIT | Just-in-time |
| OM | Operations Management |

**Tables and figures**

**Preface**

Dear reader,

As human beings, we all know that everything in life is finite and must come to an end. This is also true for the process of writing the thesis that you have before you. This master's thesis marks the final stage of my Master's in Supply Chain Management and the end of my academic journey. Looking back, the long and intense hours dedicated to conducting research and writing this thesis has given me a sense of fulfillment. I would like to express my gratitude to Mr. Fazlavi for his guidance throughout this process and for helping me broaden my understanding.

Wish you all the best for the future!

Marouane Tazrouti,

June 2025.

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# 1. Introduction

## 1.1 Background

A key aspect of operations planning is deciding how much inventory to hold (Mishra et al., 2021). Managing inventory is crucial for a firm's resource allocation (Liu et al., 2023), overall operational performance (Hançerlioğulları et al., 2016) and plays a strategic role (Cachon & Fisher, 2000). Consequently, it not surprising to see that the operations management (OM) literature has extensively explored the optimal inventory levels firms should maintain (Koumanakos, 2008). Holding too much inventory consumes physical space, increases costs and increases the risk of damage and spoilage, while a lack of inventory can lead to a loss of customers if their demand for a certain product cannot be satisfied (Koumanakos, 2008). The high storage costs particularly, weaken the competitiveness of firms that keep excess inventory (Hines & Rich, 1997). The importance of finding this optimal inventory level, gained prominence after the 1980s. During that time Womack et al. (1990) introduced the concept of 'lean production' in their influential book *The Machine that Changed the World*. Inspired by the success of the Toyota production system (TPS), which was built on lean principles, lean production primarily aims to reduce waste in manufacturing processes, including inventory waste. For example, when customer demand decreases, inventory levels are adjusted quickly in proportion to the decrease in demand (Kroes & Manikas, 2018). The book led to extensive research into lean practices, which initially focused on the automotive industry but later extended to other manufacturing and service sectors (Holweg, 2007). The principle behind reducing inventory waste is known as lean inventory management. This philosophy, also called inventory leanness, has as main objective to minimize inventory levels to reduce waste and holding costs throughout the supply chain. Excess inventory represents redundant output (Chen, 2017) and hence contradicts lean principles by contributing to waste (Shah & Ward, 2007). It also hides problems within the firm, which can only be found and addressed by reducing inventory (Hines & Rich, 1997). Examples of lean inventory management practices are just-in-time, product postponement, and Vendor Managed Inventory (VMI) (Ugarte, 2016). Inventory leanness offers several benefits: reduced costs, increased space and flexibility, and a potential competitive advantage (Lefebvre, 2024). It is also considered an indicator of a firm's efficiency (Mishra et al., 2021). Furthermore, several studies have found that inventory leanness allows firms to improve their financial performance (Capkun et al., 2009; Elking et al., 2017; (Tasdemir & Hiziroglu, 2019).

Beyond operational and financial benefits, research suggests that lean practices can also foster environmental sustainability (e.g., Inman & Green, 2018; King & Lenox, 2001). They are considered to go hand in hand with environmental practices (e.g, Mollenkopf et al., 2010; Simpson & Power, 2005), particularly because of their shared emphasis on waste reduction (Dües et al., 2013; Mollenkopf et al., 2010). Capabilities developed through lean practices can support the implementation of green practices, which enables firms to reduce environmental waste (Inman & Green, 2018). Together, lean and green practices are mutually reinforcing, creating a synergistic effect that yields greater improvements in both operational and environmental performance than when used independently (Inman & Green, 2018).
Due to growing environmental concerns and stakeholder pressures, focusing merely on profits is no longer sufficient nowadays. Firms are expected to consider their economic, environmental, and social performance, commonly referred to as the *triple bottom line* (Elkington, 1998). As a result, many companies are increasingly focused on developing more environmentally friendly processes (Garza-Reyes, 2015). In this context, lean practices therefore may play an important role beyond enhancing a firm's financial and operational performance, by also contributing to environmental sustainability.

### 1.2 Problem Indication

Piercy and Rich (2015) highlight that there is a lack of empirical studies on the link between lean practices and environmental performance. Moreover, while the literature has extensively examined the relationship between a firm's inventory leanness and financial performance (e.g., Eroglu & Hofer, 2011; Modi & Mishra, 2011; Tasdemir & Hiziroglu, 2019), its impact on environmental performance has received far less attention (Wieland & Creutzig, 2025). This is blameworthy, since supply chain activities are a major contributor of energy consumption and emitting harmful gasses (Agyabeng-Mensah et al., 2020). A firm's total greenhouse gas emissions consist mostly of supply chain emissions (Wieland & Creutzig, 2025). Moreover, the limited research in this area has yet to reach a consensus on the nature of this relationship. One might assume that lean practices, since their main objective is to reduce waste, inherently make a company more environmentally friendly — a concept known as “lean is green” (Ugarte et al., 2016). However, this assumption hasn't been thoroughly tested yet (Ugarte et al., 2016). In fact, lean practices do not always have a positive environmental impact; while some may be beneficial, others might have little to no effect. For instance, some studies suggest that certain lean practices, such as maintaining lower inventory levels, enhance environmental performance (King & Lenox, 2001; Wang et al., 2025). After all, reducing the amount of unnecessary inventory means less materials, production, transportation, and packaging, are needed which has a positive impact on the environment (Mollenkopf et al., 2010). However, Rothenberg et al. (2001) found no significant link between inventory levels and emissions. Additionally, Chen (2017) highlights that lower inventory levels require more frequent orders of smaller material quantities, potentially increasing transport emissions. Mollenkopf et al. (2010) point out that since just-in-time (JIT) practices include small lot sizes, this leads to increased transportation, packaging, and handling which might negatively impact the environment. Venkat and Wakeland (2006) note that it also depends on the length of the supply chain. Public companies often have long supply chains, and the farther those stretch, the more pollution they cause. A local supply chain usually has low emissions because travel distances are short and less stock is needed. But when a supply chain extends to regions or countries, transport emissions rise, and trying to keep lean inventories can conflict with environmental goals. Furthermore, there is a lack of evidence for integrated lean and green implementation in the real world (Hallam & Contreras, 2016). These mixed findings and opinions indicate the presence of what the literature refers to as trade-offs between lean and green (Dieste et al., 2019). Therefore, it becomes clear from the above that more evidence is needed to determine whether lean practices truly contribute to environmental sustainability and, if so, which ones. Therefore, this thesis will focus on a specific type of lean practice: inventory leanness.

As a matter of fact, previous studies also have failed to look at boundary conditions in the relationship between inventory leanness and environmental performance. This paper aims to fill this gap by examining industry competition as a potential moderator in the relationship. Traditionally, operations within firms were focused on increasing internal efficiency (Mishra et al., 2021). But it has currently been recognized that decisions at the operational level, such as those related to inventory, have a strategic importance as well, since they can affect a company’s competitive position in the market (Mishra et al., 2021). This suggests that companies base their inventory decisions not only on internal factors, but also in response to how competitors behave. Regarding environmental performance, research has indeed shown that firms also attach importance to their competitors' environmental performance. Asgharian et al. (2024), for example, point out that firms that face high competition, are more closely monitored, which forces them to improve their environmental performance. From an operations perspective, Zhou (2012) indicates that more intense competition drives firms to reduce their inventory to increase efficiency. These studies suggest that firms facing intense competition must balance the need for lean inventory, while coping with the increasing pressure to meet environmental standards. Additionally, competition has been proven to have a moderating role in a similar context. Eroglu and Hofer (2014) found that competitive intensity negatively moderated the relationship between inventory leanness and financial performance, indicating that more competition has a reduced effect on financial performance.

Given all above, it is reasonable to expect industry competition being a relevant moderator between inventory leanness and environmental performance. Therefore, the purpose of this thesis is twofold: first, to add to the limited existing literature about the relationship between inventory leanness and environmental performance. Second, to fill the gap of the lack of investigating moderators in this relationship by investigating the impact of industry competition as a potential moderator.

### 1.3 Theoretical Contributions and Managerial Implications

Studies that examine the inventory leanness–environmental performance relationship are scarce, and there is no clear consensus on whether lean inventory practices affect environmental performance. Also empirical studies investigating the broader lean–green relationship are limited (Piercy & Rich, 2015). Therefore, this study seeks to contribute both to the general lean–green literature and, more narrowly, to the inventory leanness-environmental performance relationship.
The second contribution is including a potential moderator that has not been used prior in this relationship.

The findings will also be relevant to managers by enhancing their awareness about the importance of lean inventory practices in improving sustainable performance, particularly environmental performance. They may also encourage managers to adopt or expand lean inventory management practices within their companies. It is important that managers understand the conditions under which lean inventory practices are most effective so that they will be willing to implement them (Kamada, 2024). Therefore, including industry competition as a potential moderator in this study, provides insights into when engaging in lean practices is most beneficial for enhancing environmental performance.

### 1.4 Problem Statement and Research Questions

Based on the earlier mentioned information the following problem statement is set up:

"To what extent does inventory leanness influence the environmental performance of manufacturing firms, and how does industry competition potentially moderate this relationship?"

To study the relationship between inventory leanness and environmental performance the research questions below will be answered. The theoretical questions will be answered by diving into the literature, the empirical questions by conducting regression analysis.

*Theoretical questions*

RQ1. How are inventory leanness and environmental performance conceptualized in the context of operations?

RQ2. What is the impact of inventory leanness on environmental performance?

RQ3. How does industry competition potentially moderate the relationship between inventory leanness and environmental performance?

*Empirical questions*

RQ4. How does inventory leanness influence the environmental performance of manufacturing firms?

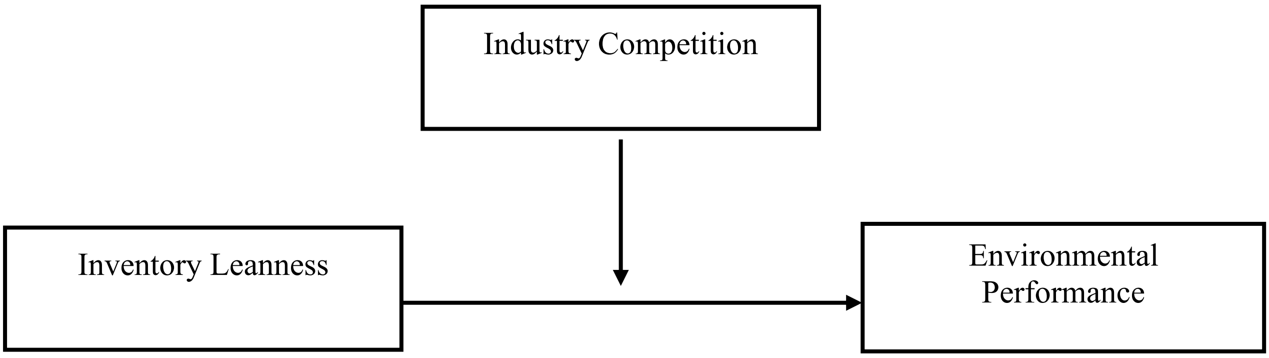
RQ5. To what extent does industry competition moderate the relationship between inventory leanness and environmental performance for manufacturing firms?

### 1.5 Conceptual Model

The following conceptual model can be created with inventory leanness as the independent variable (IV), environmental performance as the dependent variable (DV) and industry competition as moderator (M):

**Figure 1**

*Conceptual Model*




### 1.6 Structure of the Thesis

This study is divided into 5 sections: Section 2 delves into the literature to gain a comprehensive understanding of the main variables and to address the theoretical questions. Section 3 consists of the methodology and the empirical analysis. Section 4 presents the findings, followed by section 5, which discusses the results in relation to the existing literature. Lastly, section 6 concludes the study by acknowledging its limitations and offering recommendations for future research.

## 2. Theoretical Background

This section provides an overview of the existing literature on inventory leanness, environmental performance, their relationship, and the potential moderating role of competition. The aim is to address the previously outlined theoretical questions. For this, primarily two research streams were used: the lean operations management literature and the "lean and green" literature. The resource-based view (RBV) is utilized as conceptual framework to explain the relationship between inventory leanness and environmental performance.

### 2.1 Inventory Leanness

The primary goal of inventory management is to balance inventory investments and customer service (Ivanov et al., 2021). Although essential to a firm's operations, inventory is expensive (Barker et al., 2022), with inventory accounting for up to 50% of a firm's total capital investment (Ivanov et al., 2021). It involves costs related to storage, insurance, spoilage, and obsolescence risk (Callioni et al., 2005). Inventory serves multiple purposes, such as acting as a buffer against demand variability to ensure product availability, increasing supply chain flexibility by positioning inventory strategically, mitigating risks from disruptions like natural disasters and supplier bankruptcy, and benefiting from bulk purchase discounts or inflation protection (Ivanov et al., 2021). Inventory is categorized into three main types: raw materials, work-in-progress inventory and finished goods inventory (Andreou et al, 2016). Raw materials are materials which the firm bought but are not processed yet; work-in-progress inventory refers to partially completed items; finished goods are completed products which are ready for delivery (Ivanov et al., 2021).

The traditional view in inventory management has been on optimizing inventory levels (Baker, 2007). Excessive inventory levels can lead to negative outcomes, such as write-offs due to obsolescence, the need to sell items at discounted prices and a reduced capability to pursue business opportunities because of restricted resources (Hendricks & Singhal, 2009). Furthermore, it can increase lead times and make it more difficult to detect problems quickly, which prevent underlying issues from becoming visible (Hines & Rich, 1997). Conversely, holding too little inventory, increases vulnerability to supply chain disruptions (Chopra & Sodhi, 2004) and can also harm firm performance (Obermaiser & Donhauser, 2012). The need for this balance is further highlighted by Eroglu & Hofer (2011), who found that in approximately half of the industries they sampled, the relationship between inventory leanness and financial performance followed an inverted U-shape. This implies that while initial inventory reductions are beneficial, reducing inventory beyond a certain point negatively impacts firm performance. Similarly, Chen et al. (2005) observed that firms with moderately low inventory levels tended to perform very well in the stock market in the long term, whereas firms with the lowest inventory levels did not show unusual performance. This is reasonable since extremely low inventory often means minimal buffers during shortages and reduced adaptability in the face of disruptions for instance (Petitt et al., 2010).

Lean production (or lean manufacturing) is a philosophy that uses different lean practices, such as total quality management and JIT to reduce various forms of waste, like excess inventory and scrap (Womack et al., 1990). A primary objective of these practices is to minimize resource use while achieving the same outcome (Piercy & Rich, 2015). According to Shah and Ward (2003) lean production consists of four bundles: just-in-time, total quality management, total preventive maintenance, and human resource management. Lean production provides a competitive advantage for firms by reducing costs and improving efficiency and quality (Bhamu & Sangwan, 2014). Studies have shown that it leads to benefits such as reduced production lead times, shorter processing and cycle times, lower inventory levels and fewer defects and waste (Bhamu & Sangwan, 2014). Reducing inventory is a central objective of lean production (Mishra et al., 2021). Firms should maintain only the necessary inventory needed for production while removing excess stock (Kroes & Manikas, 2018). By implementing lean production methods, firms aim to achieve leaner inventories, which are expected to increase overall performance (Eroglu & Hofer, 2011).
Inventory leanness gained prominence within management in the 1980s (Cannon, 2008), which is supported by Chen et al. (2005) who found that American manufacturing and retail firms reduced their inventory levels between 1981 and 2000. Reduced inventory can yield benefits such as increased flexibility (Belekoukias et al., 2014) and shorter cash flow cycles (Kroes & Manikas, 2018). Because of its proven benefits on various performance metrics, including financial performance (e.g., Capkun et al., 2009; Eroglu & Hofer, 2011; Isaksson & Seifert, 2014) and environmental performance (King & Lenox, 2001), inventory leanness has

become a widely adopted practice in the manufacturing industry (Chuang et al., 2019). The study of Chuang et al. (2019) demonstrated that its positive effects extend are not confined to the manufacturing industry, and also extend to the retail industry. They studied the relationship between inventory leanness and operational efficiency for U.S retail firms, using panel data from 2000 to 2013. They found an inverted U-shaped relationship between the variables and that firm size and demand uncertainty moderate this relationship.

To summarize, Inventory management primary goal is to balance investment in stock against customer service, yet holding a lot of inventory leads to significant capital and incurs storage, insurance, spoilage, and obsolescence costs. Firms hold raw materials, work-in-progress, and finished goods to buffer demand variability, enhance flexibility, mitigate disruptions, and exploit bulk discounts. Too much inventory raises write-offs, lead times, and hidden issues, while too little increases disruption risk, often producing an inverted U-shaped performance curve. Lean production, using practices like just-in-time, total quality management, and preventive maintenance, aims to minimize waste, including excess inventory, boosting efficiency, quality, and environmental outcomes. Since the 1980s, lean inventory has delivered financial, operational, and sustainability benefits across manufacturing and retail.

### 2.2 Environmental Performance

The field of Operations has a significant impact on the environment (Gimenez et al, 2012). It is therefore no surprise that sustainability has become an increasingly important topic within OM. It consists of three core dimensions: the economic, environmental and social (Elkington, 1998). In this context, sustainable operations management extends the traditional profit-centred focus of OM by considering a firm’s environmental impact and its stakeholders (Kleindorfer et al., 2005). The importance of sustainability within OM is for two main reasons (Gimenez et al, 2012). First, firms should held be accountable for their resource use, and environmental footprint resulting from activities like production and transportation. Second, firms should operate responsibly by protecting employee health and contributing to the wellbeing of the overall community.

Environmental sustainability encompasses areas such as waste reduction, pollution reduction and energy efficiency (Gimenez et al., 2012). Companies face increasing pressure to adopt cleaner operations (Dieste et al., 2019) and reduce emissions (Weinhofer & Hoffmann, 2010) to minimize their negative environmental impact. The manufacturing industry in particular is widely recognized as a significant contributor to environmental degradation (Garza-Reyes et al., 2018). To achieve greater sustainability, companies therefore need to integrate these aspects throughout their supply chains. This is done by implementing environmental practices. Environmental practices can be defined as "the level of resources invested in activities and know-how development that lead to pollution reduction at the source" (Hajmohammad et al., 2013). This encompasses initiatives such as adopting environmental management systems (e.g., ISO 14001) and minimizing waste (Hajmohammad et al., 2013). Several studies have shown that adopting environmental practices leads to improved environmental performance (Agyabeng-Mensah et al., 2020; Al-Sheyadi et al., 2019). This is in line with the natural resource-based view (NRBV) that states that by investing in environmental strategies, firms can develop unique capabilities which provide a competitive advantage and lead to improved environmental performance (Hart, 1995).

Several studies have shown that companies can also benefit financially from embracing environmentally friendly practices. Furthermore, to maintain competitiveness firms need to balance economic, environmental and social objectives (Cherrafi et al., 2017). On the other hand, by wasting resources, they might miss out on business opportunities.

Environmental performance reflects how a firm's operations and products impact the environment (Klassen & Whybark, 1999). This can be in in physical terms or in financial value terms, but mostly this is measured in physical terms (Albertini, 2013). The physical part encompasses a wide range of indicators such as CO2 emissions, waste and water use. These indicators can be further divided into input-focused (e.g, resource use) and output focused (e.g, emissions and waste) (Albertini, 2013). Dieste et al. (2019) reviewed 72 studies on the relationship between lean practices and environmental performance, and identified the most commonly used environmental performance indicators as air emissions, consumption of water, energy, and materials, solid waste, water pollution and use of toxic chemicals.

### 2.3 Inventory Leanness and Environmental Performance

Stakeholder pressures about the environment have led manufacturing firms to make their internal processes more environmentally friendly by among others implementing lean practices (Vachon & Klassen, 2006). The reasons for implementing lean practices and environmentally friendly practices can be divided into internal reasons and external reasons. Internal reasons are for example increasing profitability (Kleindorfer et al, 2005). External reasons are government regulations (Kleindorfer et al., 2005) and customer pressure (Vachon & Klassen, 2006). Most studies in the literature indicate that lean practices positively influence a firm's environmental performance (Dieste et al., 2019). Some arguments that have been mentioned in favor of this link are that inherently both lean practices and environmental practices focus on reducing waste (e.g, Inman & Green, 2018; Mollenkopf et al., 2010; Rothenberg et al., 2001); prior existence of lean practices within a company reduces the cost and increases the ease of implementing environmental practices (Rothenberg et al., 2001); using less materials reduces pollution (Florida, 1996; Hallam & Contreras, 2016). Hajmohammed et al. (2013) provided empirical evidence that the link between both concepts is explained by environmental practices acting as a mediator. Based on survey-based data from Canadian manufacturing plants, they found that lean practices didn't directly improve environmental performance, while through environmental practices it did. The authors suggest that lean practices allow developing skills and experience that make it easier to adopt more effective environmental practices, an idea also supported by earlier research (Rothernberg et al., 2001). Hallam and Contreras (2016) reviewed 60 peer-reviewed articles and found that most studies suggested that lean practices help companies to increase environmental performance. This is because when companies cut down on waste, like excess inventory, they also use fewer resources and therefore create less environmental pollution (Hallam & Contreras, 2016).

A theory that can explain the link between inventory leanness and environmental performance is the resource-based view (RBV). RBV theory states that companies can gain a competitive advantage by having a special set of resources (Barney, 1991). These resources can be tangible, like factories and inventory, or intangible, like technology and information. For these resources to give a company a long-lasting competitive advantage, they need to be valuable, rare, hard to imitate, and difficult to be replaced (Barney, 1991). In this view inventory leanness can be seen as a valuable tool. First from the experience side. As mentioned earlier, Rothenberg et al. (2001) stated that prior existence of lean practices within a company reduces the cost companies and makes implementing environmental practices easier. Based on this it could be argued that firms that have implemented lean inventory practices for quite a long time could keep getting better by learning more new things and learning from their mistakes, which enable them to lower costs and improve their processes by making them more efficient. This leads to a competitive advantage for the firm.

While the link between inventory leanness and financial and operational performance has been quite extensively studied in the literature (e.g., Cannon, 2008; Capkun et al., 2009; Chuang et al., 2019; Eroglu & Hofer, 2011; Koumanakos, 2008), the link with environmental performance has been largely neglected. Several studies have found a relationship between inventory leanness and environmental performance in the manufacturing industry, although providing mixed results. King and Lenox (2001) investigated the relationship between lean production and environmental performance using a large dataset covering 17,499 US manufacturing firms from 1991 to 1996. They measured environmental performance through emissions of chemicals, both in absolute terms and relative to industry peers. For lean production they used a firm's maximum annual inventory of chemicals, with lower maximum inventory reflecting greater inventory leanness. By performing regression analysis, they found that firms with leaner inventories emitted fewer pollutants and generated less waste, indicating a positive relationship between inventory leanness and environmental performance. A recent study by Wang et al. (2025) examined the non-linear relationship between inventory leanness and ESG (Environmental, Social, Governance) performance, using a large panel data set of Chinese manufacturing firms. They performed a Two-Stage Least Squares (2SLS) regression analysis. They found an inverted U-shaped relationship, suggesting that moderate levels of inventory leanness enhance ESG performance, whereas excessive leanness can be detrimental. Compared to this study, Wang et al. (2025) adopted different measures: they used the empirical leanness indicator (ELI) method developed by Eroglu and Hofer (2011) to measure inventory leanness and the Lerner Index for market concentration. Furthermore, the sample of Chinese firms may limit the generalizability of the findings, due to the specific characteristics of China's market and regulatory environment (Wang et al., 2025). On the contrary, the findings of Rothenberg et al. (2001) contrast the 2 studies above. They studied the relationship between lean manufacturing practices and environmental performance in 31 automobile assembly plants in North America and Japan. Lean manufacturing was assessed through several indicators, one being "buffer minimization" which included low inventory. Environmental performance was measured using data on air emissions and resource, with the latter encompassing water and energy consumption. Based on data from surveys and interviews, they found counterintuitively that low inventory was associated with higher emissions. Regarding resource use, the findings were mixed: survey results indicated a positive association between lean inventory and resource use, while interviews suggested a negative relationship, implying improved resource efficiency. However, it should be noted that the “buffer minimization” indicator was a combination of several variables (including low inventory) that were combined into one index. This makes it more difficult to isolate the effect of low inventory on environmental performance and therefore to draw a robust conclusion. Furthermore, the sample size was relatively small. Moreover, a reason why lean practices may not lead to improved environmental performance is that low inventory levels may lead to increased emissions. Firms with lean inventories tend to place smaller, more frequent orders, resulting in more frequent deliveries from their suppliers (Plambeck, 2012). This can also involve shorter lead times, which might induce suppliers to choose for faster but less environmentally friendly transportation modes (e.g., airplanes instead of container ships). Additionally, suppliers may need to produce in smaller batches, which requires more frequent machine setups (Chen, 2017).

To summarize, above shows that manufacturing firms face both internal and external motivations to implement lean and green practices. Internally, firms pursue lean practices to improve profitability, while externally stakeholder pressures from customers, regulators, and societal expectations drive environmental initiatives (Kleindorfer et al., 2005; Vachon & Klassen, 2006). The resource-based view provides a theoretical basis, framing inventory leanness as a valuable, rare, and hard-to-imitate capability that supports long-term competitive advantage (Barney, 1991). Empirical studies produce mixed findings. King and Lenox (2001) find a clear positive link between reduced chemical inventories and lower emissions in US manufacturing. Wang et al. (2025) report an inverted U-shaped relationship in Chinese firms, where moderate leanness improves ESG performance, but excessive leanness may harm it. Rothenberg et al. (2001), surveying North American and Japanese assembly plants, offer more nuanced results, in which low inventory sometimes correlates with higher emissions due to combined indicators. Mechanisms such as more frequent deliveries and smaller production batches may offset lean benefits (Plambeck, 2012; Chen, 2017). Although above review shows mixed findings, the results of King and Lenox (2001) and Wang (2025), along with the conceptual reasoning, suggest stronger evidence for a positive association between inventory leanness and environmental performance is stronger. Therefore, H1 is stated as follows: *inventory leanness is positively associated with environmental performance.*

### 2.4 The Moderating Role of Industry Competition

Companies in highly competitive industries have as main concern reducing costs, and one common way is by holding less inventory. Smaller stock levels mean lower storage and financing costs, and they also cut waste and emissions, which improves environmental performance (King & Lenox, 2001). However, when firms focus only on cutting inventory costs, they might spend less on environmental initiatives, which can hurt their green efforts. Wang et al. (2025) point out that in these fast-paced markets, trying to keep inventory as low as possible can backfire since cash is tied up which can not be used for environmental practices. At the same time, some firms in competitive markets keep extra safety stock to avoid running out of items and upsetting customers. While this buffer helps maintain service levels, it also raises the risk of overstock, which leads to spoilage, waste, and higher emissions. So competition can push companies both toward leaner inventories and toward holding more stock, with conflicting impacts on the environment.

In less competitive markets, a few large firms often dominate. These companies can afford to hold more inventory—they face less pressure to cut every cost and can negotiate better deals with suppliers (Wang et al., 2025). Holding more stock can raise waste and emissions, but big firms are also more visible to other stakeholders, such as regulators. As a result, they tend to invest in green processes and cleaner technologies. These investments can offset the environmental costs of carrying extra inventory.

Putting these ideas together, industry competition might affect the link between inventory leanness and environmental performance. In highly competitive industries, the drive for both cost savings and customer service can sometimes strengthen but at other times undermine a firm’s green performance. In markets with low competition, large firms have the resources to balance higher stock levels with strong sustainability programs.

Based on this, hypotheses 2 is proposed: in highly competitive industries, keeping extra stock weakens the positive effect of low inventory on the environment; in low-competition industries, dominant firms can cut inventory and still invest in green practices, strengthening environmental performance.

# 3. Research Methodology

This section outlines the research methodology employed in this study. First, the research nature and strategy will be discussed. Consequently, the data collection and cleaning process are discussed in-depth. This is followed by the descriptions and measurements of the dependent variable, independent variables, moderator and control variables. Lastly, the data analysis, includes the regression models and briefly mentions the measures that were taken to ensure the robustness and validity of the results.

## 3.1 Research Nature and Research Strategy

This thesis employed a quantitative and deductive approach, since this was most suitable. Quantitative research has 3 main benefits: standardization, scalability and speed (Lim, 2025). With standardization is meant that the data is all in the same format, for example every respondent gets asked the same survey questions. Scalability is also a benefit, because it allows for including more participants or data points easily. This enhances the results of the study and its generalizability (Lim, 2025). Speed allows for collecting and process data fast. This means results can quickly be obtained and more flexibility to adjust plans or decisions. Because this thesis is about whether manufacturing firms with leaner inventories have better environmental performance, the unit of analysis is the firm. Furthermore, a longitudinal study design was adopted, to enhance the robustness of the results, and to address the call by Dieste et al. (2019) for more longitudinal studies on this topic. They argue that most existing research examined the relationship between lean practices and environmental performance at a single point in time, which limits the ability to observe changes and transformations over time. Earlier, Piercy and Rich (2015) pointed out the lack of empirical studies on the link between lean practices and environmental performance.

When conducting a longitudinal study, a choice must be made between using quarterly or annual data. Quarterly data allows researchers to obtain more data points because of the shorter time intervals (Flannery & Hankins, 2013). A disadvantage, however, is that changes between quarters are typically smaller than changes between years. This may reduce the accuracy of the estimated coefficients in the study. The opposite holds true for annual data: using annual data means having relatively fewer data points, but the longer timeframe allows for more meaningful changes to be observed (Flannery & Hankins, 2013). For this study, annual data was chosen.

To test the hypotheses, secondary data was collected over a six-year period from 2017 to 2022. Secondary data offers several advantages over primary data, such as less requirement of resources and time (Dunn et al., 2015), making it particularly suitable for longitudinal studies (Davis-Kean et al., 2015), and providing access to large datasets, enhancing thereby the generalizability (Dunn et al., 2015). A limitation of using secondary data, on the other hand, is the possibility of incomplete datasets. This must be carefully addressed, by for example removing firms with any missing data, to ensure the reliability and validity of the findings.

### 3.2 Data Collection and Cleaning

The hypotheses were tested using secondary data. Firm-level data was collected from Compustat North America Fundamentals Annual, accessed through Wharton Research Data Services (WRDS), and Refinitiv. Industry-level sales data was also retrieved from Compustat. Compustat is a widely used database, that encompasses more than 90% of global market globalization and 80 countries, offering financial and market data on public companies (Sancha et al, 2023). Refinitiv is well known for its comprehensive ESG database with more than 800 metrics, which covers 90% of the market global capitalization (LSEG, n.d.).

This study made use of non-probability sampling, since firms were subjected to different criteria. Firms had to be (a) active for every year, (b) have positive sales and inventory values, and non-zero assets (c) have data available on all variables over fiscal years 2017-2022. The criterion of positive sales and inventory was adopted from Eroglu and Hofer (2011).

This study focused on different sub-industries within the U.S. manufacturing sector, which are classified under North American Industry Classification System (NAICS) codes 31–33. The reason for this particular sample was that data on these firms is often easily accessible in

databases. Another reason for focusing on manufacturing firms was because lean principles are essential within the manufacturing industry (Wong et al., 2014) and lean practices are widely applied especially within this industry (Garza-Reyes et al., 2012).
A cross-industry study (including sub-industries) was preferred over a single industry, since this allows for inter-industry comparison on variables such as the HHI. Moreover, including multiple industries allows for controlling variations that may arise due to industry-specific characteristics, which improves the generalizability of the findings (Modi & Mishra, 2011).

Following above criteria, the data cleaning process went as follows. First, data was extracted from Compustat. Filters were applied to keep only firms with a NAICS code starting with 31, 32, or 33, inventory and sales greater than zero, non-zero assets and active status. This resulted in 9295 observations. Subsequently, firms missing data for any fiscal year were removed, leaving 7500 observations corresponding to 1250 firms.
Next, ESG data for each firm was collected from Refinitiv using ticker symbols. In this step firms were excluded for two reasons: missing values for the environmental pillar score in at least one year and recording a score of zero for at least one year. The latter indicates a lack of disclosure of information from the firm (Sahin et al, 2022) and including such firms could introduce bias. Additionally, Refinitiv considered some firms to have actually a NAICS code outside the 31-33 range, hence those were removed as well. After this step, 3138 observations remained, representing 523 firms.
Then, the dataset was inspected for missing values in the control variables. For firms with missing R&D expenses, the value was set to zero, following prior studies (e.g., He & Wintoki, 2016; Lin et al., 2021). This was done to avoid losing 501 observations, which would be substantial, and because R&D intensity was only a control variable, the potential bias of keeping them was considered to be insignificant.
Four firms were missing data on long-term debt. For three of them, the missing values were set to zero, as their debt was consistently zero in other years. For the remaining firm, which had non-zero debt in earlier years, the two missing values were replaced by the mean over the other four years.
Consequently, five firms were removed because their subindustry contained less than five firm, to prevent bias in the HHI calculation (Laksmana & Yang, 2015). This resulted in a total of 3108 observations from 518 firms.
Lastly, subindustry sales were collected, including both active and inactive firms, with the condition that sales must be greater than zero, as was set earlier for firm-level sales data. No

additional firms were excluded after this step. The final sample therefore consists of 3108 firm-year observations from 518 firms. Appendix A lists the NAICS subindustries included, and the number of firms each subindustry contains.

## 3.3 Sample & Databases

### 3.3.1 Independent Variable

The independent variable is inventory leanness. Inventory leanness has been measured in various ways in previous studies (Eroglu & Hofer, 2011). Three main groups of measures can be identified (Eroglu & Hofer, 2011): absolute measures, such as average or maximum inventory levels (e.g. King & Lenox, 2001); standardized measures, such as inventory turnover or inventory-to-sales ratio (e.g. Capkun et al., 2009; Chen et al., 2005); and complex analytical measures that require expert knowledge, making them less practical for managers. Following Capkun et al. (2009), Chen et al. (2005), Obermaier and Donhauser (2012), this study used inventory-to-sales ratio as the measure for inventory leanness. Inventory-to-sales ratio was computed by dividing the Compustat variables INVT (representing total inventory) by SALE (representing net sales). A lower inventory-to-sales ratio indicates higher inventory leanness.

In formula form:

$$Inventory - to - sales\ ratio = \frac{Total\ inventory}{Net\ sales} \tag{1}$$

### 3.3.2 Dependent Variable

Environmental performance was measured by using the environmental pillar score (E pillar) from Refinitiv, which ranges from 0 to 100 percent. It reflects a company's relative environmental performance within its industry (Hinton, 2021). If a company has a score of 75%, for example, this means it performs better than 75% of other companies in its industry.

It is divided into three categories: resource use, emissions and innovation (LSEG, n.d.). It is defined in Refinitiv as ‘The environmental pillar measures a company's impact on living and non-living natural systems, including the air, land and water, as well as complete ecosystems. It reflects how well a company uses best management practices to avoid environmental risks and capitalize on environmental opportunities in order to generate long term shareholder value.’.

### 3.3.3 Moderator Variables

The extent of industry competition was measured using the Herfindahl-Hirschman Index (HHI), which has been widely used as a proxy for industry competition in prior studies (e.g., Chen et al., 2021; Gao et al., 2017; Tang, 2018). It takes a value between zero and one. A HHI equal to one indicates that a single firm dominates the entire market, which reflects a monopoly (Li et al., 2020). A value close to zero suggests that many firms hold similar market shares, which indicates a highly competitive industry (Li et al., 2020). Therefore, the higher the HHI, the less competitive — and thus the more concentrated — the market is (Wang et al., 2023). A HHI between 1000 and 1800 represents moderate concentration within an industry, while an HHI-value higher than 1800 indicates a highly concentrated industry (U.S. Department of Justice, 2024). Translated to the 0-1 scale used in this thesis, this corresponds to values between 0.10 and 0.18 for moderate concentration, and values above 0.18 for high concentration.

The HHI of various subsectors within the manufacturing industry (NAICS 31-33), grouped at the three-digit NAICS level, was calculated using the variable SALE from Compustat, following prior studies (e.g., Giroud & Mueller, 2010; He & Wintoki, 2016; Hong & Liu, 2023). Each firm's market share was computed by dividing its sales by the total sales of all firms in the same industry. The HHI was then calculated by squaring each firm's market share and consequently summing them.

In formula form:

$$HHI_{j,t} = \sum_{i=1}^{N_{j,t}} \left(s_{i,j,t}\right)^2 \qquad (2)$$

Where $s_{i,j,t} = \frac{\text{Sales of firm } i \text{ in year } t}{\text{Total sales in subindustry } j \text{ in year } t}$

$N_{j,t}$ is the number of firms in subindustry *j* in year *t*

### 3.3.4 Control Variables

To isolate the relationships that were being studied to ensure robustness, control variables were added. First of all, firm size was included, since bigger firms will have more money to invest in environmental practices. This was calculated by taking the natural logarithm of the assets of a firm (Zhang, 2021). Firm age was included, since older firms might have more experience with conducting and improving their environmental practices. This was calculated by the difference between year of incorporation of a firm and observation year (Mahran & Elamer, 2025). R&D intensity was included, because firms with higher degree of innovation may improve their environmental practices what influences their environmental performance. This was calculated by dividing R&D expenses by sales (Zhong et al., 2020). Leverage was included and calculated by dividing total debt by total assets (Chen et al., 2017). Capital intensity was also included and calculated by dividing net property, plant and equipment by total assets (Gross et al., 2016). Finally, ROA was included and calculated by dividing income before extraordinary items by total assets (Bailey, 2022).

An overview of the relevant variables is presented below in Table 1.

**Table 1**

*Variables of Interest*

| Variable | Description | Origin |
|---|---|---|
| ***Dependent variable*** | | |
| Environmental pillar score | Score between 0 and 100 representing a percentile rank | Refinitiv |
| ***Independent variable*** | | |

| | | |
|---|---|---|
| Inventory-to-sales ratio | Total inventory (INVT) divided through net sales (SALE) | Compustat |
| ***Moderator variable*** | | |
| HHI | The sum of squared market shares of all firms in a particular industry and year | Compustat |
| ***Control variables*** | | |
| Capital intensity | Property, Plant & Equipment - total (PPENT) divided by total assets (AT) | Compustat |
| Firm age | Observation year minus "Date of incorporation" | Refinitiv |
| Firm size | Natural logarithm of total assets (AT) | Compustat |
| Leverage | Long-term debt (DLTT) plus debt in current liabilities (DLC) divided by total assets (AT) | Compustat |
| ROA | Income before extraordinary items (IB) divided by total assets (AT) | Compustat |
| R&D intensity | R&D expenses (XRD) divided by sales (SALE) | Compustat |

### 3.4 Data Analysis

#### 3.4.1 Models

For the data analysis, regression analysis was used since both variables can be quantified, using Stata as statistical software. The equations below were tested for each firm *i* in year *t* of the sample. Model 1 (equation 3) represents the main relationship between inventory leanness and environmental performance. Following Wang et al. (2025), inventory leanness was lagged by one year, to reduce potential endogeneity issues such as reverse causality. Another reason was that it might take some time before the effects of inventory leanness on environmental performance become apparent. Model 2 (equation 4) estimates the moderation effect by incorporating the interaction term *inventory leanness * competition*; $\alpha$ represents the constant and $\varepsilon$ denotes the error term that explains the variation in the DV. Firm size was included since larger firms tend to have relatively lower inventory levels (Rumyantsev & Netessine, 2007). Control variables are grouped under *Controls*. Year is a dummy variable that represents year fixed effects.

$$Environmental\ Performance_{i,t} = \alpha + \beta_1 Inventory\ Leanness_{i,t-1} + \beta_2 Controls_{i,t} + \beta_3\, Year + \varepsilon_{i,t} \quad (3)$$

$$Environmental\ Performance_{i,t} = \alpha + \beta_1 Inventory\ Leanness_{i,t-1} + \beta_2 Industry\ Competition + \beta_3 (Inventory\ Leanness * Industry\ Competition) + \beta_4 Controls_{i,t} + \beta_5\, Year + \varepsilon_{i,t} \quad (4)$$

### 3.4.2 Reliability and Validity

First of all, to increase the reliability of the results, this thesis ensured the use of a balanced dataset, which means that all firms had complete data for all variables across all years. Additionally, all variables were examined for outliers using box plots. For example, some firms had an incorporation year that was later than the observation year, which resulted in a negative firm age. This was often because a company had changed its name or had been acquired by another firm. For these firms, the incorporation year was replaced with the original founding year, which preceded the observation period.
Furthermore, the Variance Inflation Factor (VIF) was calculated to test potential

multicollinearity. Typically, multicollinearity is a concern when the VIF is greater than ten (Petter et al., 2007). A mean VIF of 1.11 was found (see Appendix B), which indicates that multicollinearity was not present.
Also, year dummies were included to control for time-varying shocks, such as the COVID-19 pandemic.

A key assumption in panel data analysis is the absence of autocorrelation (Born & Breitung, 2016), although this assumption is often violated in practice (Leszczensky & Wolbring, 2022). Therefore, standard errors were clustered at the firm level in all fixed effect regressions. Additionally, the Wald test was performed to test for heteroskedasticity. A p-value of 0.0000 was returned which indicated that heteroskedasticity was present (See Appendix B). Finally, both fixed effects and random effects models were estimated, after which the Hausman test was conducted to determine whether a fixed effect regression was a must. The Hausman test returned a p-value of 0, which indicated that the random effects model is inconsistent and that a fixed effects model was preferred.

## 4. Findings

This section presents the empirical results of the study. First, the descriptive statistics and correlation coefficients are displayed in tables and briefly discussed. Second, the findings from the fixed effect regressions for both models 1 and 2 are presented and discussed. The last part in this section, mentions measures that were implemented, such as an alternative measure for inventory leanness and winsorization of some variables, to increase the robustness of the findings.

### 4.1 Descriptive Analysis

Table 2 reports the descriptive statistics of all variables over 3108 firm-year observations. One of the things that stands out is the large standard deviation (26.76) of the environmental pillar score. Some firms have a very bad environmental performance (min=0.56), while others score very high (max=98.80). This indicates high variation in environmental scores across firms. Inventory-to-sales has a mean of 0.16, which indicates that firms on average hold inventory equal to 16 % of their annual sales, but some hold almost no inventory (min = 0.00) while

others have high stocks (max= 1.39) that exceed their sales. The HHI shows a mean of just 0.05, which implies that most subindustries are highly competitive. The maximum HHI-value of 0.25 shows also the presence of high  concentrated industries in the sample.
Besides, firm age has a mean of 44.94 years and the sample includes some very young firms (1 year) and extremely old firms (204 years). This is reflected in the high standard deviation (SD 36.21). Finally, R&D intensity has a mean of 0.05 and SD of 0.08 with a minimum value of 0 and a maximum value of 0.86. This suggests that in some industries R&D, for example the pharmaceutical industry, is crucial while in others not.

**Table 2**

*Descriptive Statistics (N=3108)*

| | Mean | SD | Min | Max |
|---|---|---|---|---|
| Environmental score | 52.46 | 26.76 | 0.56 | 98.80 |
| Inventory-to-sales | .16 | .10 | 0.00 | 1.39 |
| HHI | .05 | .04 | 0.02 | .25 |

| | | | | |
|---|---|---|---|---|
| Capital intensity | .24 | .16 | 0.02 | .88 |
| Firm age | 44.94 | 36.21 | 1.00 | 204 |
| Firm size | 8.82 | 1.69 | 3.76 | 13.31 |
| Leverage | .29 | .16 | 0.00 | 1.43 |
| ROA | .05 | .09 | -1.58 | .63 |
| R&D intensity | .05 | .08 | 0.00 | .86 |

Table 3 reports the correlation coefficients among the nine main variables. Several patterns stand out. First, the correlation between the inventory-to-sales ratio and environmental score, prior to running fixed effects regression analysis, suggests a negative relationship that is statistically significant. This implies that firms with a higher inventory-to-sales ratio tend to have worse environmental performance, which provides initial support for hypothesis 1. However, the size of the coefficient ($\beta = -0.089$) indicates that this relationship is weak. Second, HHI is weakly positively correlated with environmental score (0.031, $p<0.10$) but uncorrelated with inventory leanness ($\beta = -0.013$ and p-value is not significant). This implies that firms in more concentrated subindustries might have slightly better environmental performance, but the degree of competition does not affect how lean their inventories are. Inventory-to-sales correlates negatively with capital Intensity (–0.120, $p<0.01$) which indicates that leaner firms are less capital-intensive, which make sense given their main objective of minimizing waste. Furthermore, the correlation between firm size and environmental score is positive and very strong, which suggests that larger firms tend to perform better environmentally. This positive association was expected, as larger firms typically have more resources available to invest in environmental practices. The correlation between firm age and environmental score is also positive and quite strong, which indicates that older firms tend to have greater environmental performance. This also aligns with what was expected, since older firms are more likely to have accumulated experience in implementing and improving their environmental practices and strategies.

**Table 3**

*Correlations*

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9 |
|---|---|---|---|---|---|---|---|---|---|
| (1) Environmental score | 1 | | | | | | | | |
| (2) Inventory-to-sales | -0.089*** | 1 | | | | | | | |
| (3) HHI | 0.031* | -0.013 | 1 | | | | | | |
| (4) Capital intensity | 0.010 | -0.120*** | 0.186*** | 1 | | | | | |
| (5) Firm age | 0.225*** | -0.036** | 0.077*** | -0.008 | 1 | | | | |
| (6) Firm size | 0.688*** | -0.138*** | -0.010 | 0.020 | 0.210*** | 1 | | | |
| (7) Leverage | 0.135*** | -0.038** | 0.022 | 0.056*** | 0.031* | 0.230*** | 1 | | |
| (8) ROA | 0.126*** | -0.143*** | 0.019 | -0.045** | 0.028 | 0.127*** | -0.070*** | 1 | |
| (9) R&D intensity | -0.015 | -0.008 | -0.231*** | -0.294*** | -0.141*** | -0.023 | -0.187*** | -0.075*** | 1 |

*** *p<0.01,* ** *p<0.05,* * *p<0.1*

## 4.2. Regression Results

Table 4 presents the fixed-effects regression results. Model 1 is the baseline model without HHI; model 2 includes HHI and its interaction with lagged inventory-to-sales. Because inventory-to-sales was lagged by one year the number of observations is equal to 2590 observations. In Model 1, a unit increase in lagged inventory-to-sales leads to 16.4 percentage points decline in environmental score ($\beta = -16.374$, $p < 0.05$). This demonstrates that lagged inventory-to-sales ratio has a strong and statistically significant negative effect on environmental score in the following year, even after accounting for capital intensity, firm age, firm size, leverage, profitability, R&D intensity, and time shocks. This suggests that firms that hold more inventory tend to have lower environmental performance compared to leaner firms. This is in line with H1 which stated that inventory leanness is positively associated with environmental performance.

Additionally, only capital intensity, firm age and firm size are significant as control variables. Leverage ($\beta$=–2.044, SE = 3.646), ROA (0.764, SE = 2.831), and R&D intensity (7.727, SE = 8.278) are not significant in the baseline model. Capital intensity is positively related to environmental score ($\beta$=32.136, $p < 0.01$), which suggests that firms with high capital tend to have better environmental performance. Firm age ($\beta$=2.74, $p < 0.01$) and firm size ($\beta$=5.425, $p < 0.01$) both improve environmental performance, which may be because older firms have

more experience implementing and enhancing their environmental practices, while larger firms possess greater resources to invest in effective environmental initiatives.
In Model 2 the inventory-to-sales coefficient becomes slightly more positive (β =–13.171), but loses its significance, while the main HHI effect is negative (β =–35.824) and also not significant. Similarly, the interaction term (β =–77.439) is also not significant. The $R^2$ rises only by .001 compared to model 1, which indicates that adding HHI and its interaction do not improve the fit of the model.

To sum up, while inventory leanness is associated with better environmental performance in the baseline model, neither HHI alone nor its interaction with leanness are statistically significant in model 2. This means that HHI does not moderate this relationship. Inventory leanness seems to improve environmental performance equally in both low concentrated subindustries and more concentrated subindustries.

**Table 4**

*Baseline Model and Moderation Model Including HHI*

| Variables | Model 1 (baseline) | Model 2 (moderation) |
|---|---|---|
| Lagged Inventory-to-sales | -16.374** | -13.171 |
| | (6.389) | (12.595) |
| Capital intensity | 32.136*** | 32.575*** |

| | | |
|---|---|---|
| | (8.374) | (8.39) |
| Firm age | 2.74*** | 2.767*** |
| | (.199) | (.2) |
| Firm size | 5.425*** | 5.46*** |
| | (1.414) | (1.421) |
| Leverage | -2.044 | -1.761 |
| | (3.646) | (3.635) |
| ROA | .764 | .791 |
| | (2.831) | (2.829) |
| R&D intensity | 7.727 | 7.812 |
| | (8.278) | (8.248) |
| HHI | | -35.824 |
| | | (59.049) |
| Lagged Inventory-to-sales x HHI | | -77.439 |
| | | (241.586) |
| Constant | -123.97*** | -123.661*** |
| | (12.117) | (12.138) |
| Observations | 2590 | 2590 |
| Year dummies | yes | yes |
| $R^2$ | .296 | .297 |

*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

**4.3 Robustness Checks**

To ensure the reliability of the findings several robustness checks were done. First lagged inventory-to-sales was replaced by non-lagged inventory-to-sales in both regression models. For the baseline model, this made the effect on environmental score slightly more negative (-16.37 vs -17.59) while the p-value decreased from 0.011 to 0.000, making it also significant at the 1% level. For the moderator model, this resulted in the lagged inventory-to-sales coefficient increasing from -13.17 to -21.33, whereas the p-value went from non-significant to significant at the 1% level (0.296 vs 0.008). Hence, using non-lagged inventory-to-sales strengthened the relationship between the IV and DV, both in terms of the magnitude of the coefficients and their significance levels, particularly for the interaction model. Furthermore, four control variables (capital intensity, leverage, ROA, R&D intensity) were winsorized at the 1% level, after which the baseline model and moderator model were run again to assess whether this would change the size of their coefficients and significance levels. The results remained unchanged, which confirmed that the inspection of outliers during the data cleaning period was conducted successfully.

Additionally, an alternative measure for inventory leanness, the ELI (Empirical Leanness Indicator), was used. Eroglu and Hofer (2011) introduced this measure, which compares a particular company to other companies of similar size in the same industry. Specifically, it captures the difference between a firm's inventory turnover and its industry's turnover curve. A higher ELI score indicates greater inventory leanness. The reason for developing this measure was because they believed traditional measures, such as inventory turnover, fail to account for industry-specific characteristics and ignore economies of scale. A benefit of using the ELI measure is that it helps managers identify the level of leanness that, on average, leads to the best performance within their industry (Eroglu & Hofer, 2011). After its introduction the ELI measure has been used by various studies (e.g, Hofer et al., 2012; Isaksson & Seifert, 2014; Lefebvre, 2024; Wang et al., 2025).

The ELI was calculated as follow. First, companies were grouped by subindustry and year to make fair comparisons. For each company, the natural logarithm of total sales and total inventory was taken and OLS regression was performed. The difference between the actual inventory and the expected inventory based on sales was calculated, which represented the residuals. A negative residual, indicates that the actual inventory is less than expected, meaning the firm is relatively leaner. A positive residual means that the firm holds more inventory than expected, hence being relatively less lean. Finally, to obtain the ELI-values the standardized residuals were multiplied by -1.

Above can be written like equation 4 below, with $\alpha$ representing the intercept and $\varepsilon$ representing the residual.

$$\ln(inventory) = \alpha + \beta \ln(sales) + \varepsilon \tag{4}$$

Then, new regressions with lagged ELI were run for the baseline model and moderator model, and as expected, also the ELI was associated with an increased environmental performance. In the baseline model, for each one standard deviation increase in ELI, the environmental score increases by about 2.3 percentage points. The p-value was significant the 1% level (p=0.002), which made the findings robust. In the moderator model, for each one standard deviation increase in ELI, the environmental score increases by 3.063 percentage points. The p-value was significant at the 1% level (p=0.003). The regression results are reported in Appendix C.

# 5. Discussion

This section discusses the main findings of this study, by mentioning their theoretical contributions and managerial relevance.

## 5.1 Theoretical Contributions

Many past studies have found that inventory leanness leads to greater financial and operational performance (e.g., Cannon, 2008; Capkun et al., 2009; Chuang et al., 2019; Eroglu & Hofer, 2011; Koumanakos, 2008), but the research on the inventory leanness-environmental performance relationship is limited. Only three studies were found that specifically investigated the link between inventory leanness and environmental performance. In the first place, there is already limited empirical evidence on the lean-green link (Piercy and Rich, 2015). Hence, this study aimed to add to the broader lean-green literature as well as the specific inventory-leanness-environmental performance link.

Based on the results that were verified with various robustness checks, such as using the ELI as alternative measure for inventory leanness, this thesis found that leaner firms are associated with greater environmental performance. The findings therefore reveal that inventory leanness delivers not only financial gains for firms but also environmental improvements.

This is in line with several prior studies that have investigated this relationship and found the same results (King & Lenox, 2001; Wang et al., 2025). King and Lenox (2001) examined a cross-section of 17,499 U.S. manufacturing firms over 1991–1996, using maximum annual chemical inventories as their proxy for leanness. They found a negative association between inventory levels and emissions. Firms that hold lower inventories emitted fewer pollutants. Wang et al. (2025) analyzed a panel of Chinese manufacturing firms and found an inverted U-shaped relationship between ELI and overall ESG performance. Their results suggest that moderate leanness enhances ESG scores, but extreme inventory reduction is harmful. Rothenberg et al. (2001) also studied the link but did not find evidence for a positive association between inventory leanness and environmental performance.

Finding a positive link was not surprising since conceptually many arguments have been mentioned for a positive association between the lean practices and environmental performance, such as their joint focus on reducing waste (e.g, Inman & Green, 2018; Mollenkopf et al., 2010; Rothenberg et al., 2001); having experience with lean practices makes it easier to implement environmental practices (Rothenberg et al., 2001) and using fewer resources leads to lower pollution (Florida, 1996; Hallam & Contreras, 2016). The second contribution was the incorporation of a potential moderator into this relationship, to address the absence of moderator-based analyses in prior studies.
While conceptually it was argued that industry competition would moderate this relationship, the results demonstrate a non-significant effect. A reason could be because of little variation in the sample. Most firms (almost 90 %) are from highly competitive subindustries (HHI < 0.10.). Wang et al. (2025) looked at a similar moderator (market concentration), using the Lerner index as proxy. In contrast to this paper, market concentration was found to be a significant moderator.

### 5.2 Practical Implications

The findings of this study should encourage managers even more to implement lean inventory practices, since they not only enhance their financial and operational performance but also their environmental performance. They should view inventory reduction not only as a cost-cutting measure but as an integral component of their sustainability goals. By treating environmental practices and inventory metrics as mutually reinforcing, firms can align operational goals with broader environmental goals. For this they need to work together. A collaborative mindset fosters shared ownership of lean-green objectives.

# 6. Conclusion

## 6.1 Research Summary

This thesis aimed to study the relationship between inventory leanness and environmental performance for 518 US manufacturing firms by using longitudinal data spanning six years. The results clearly indicate a positive link between inventory leanness and environment performance, which implies that leaner firms exhibit greater environmental performance. Using ELI as an alternative measure for inventory leanness and non-lagged inventory leanness led to the same results. The potential role of industry competition as a moderator was also investigated. While conceptual reasoning indicated that it could moderate the relationship, after testing this empirically it appeared to be non-significant.

## 6.2 Limitations and Future Research Directions

As with all empirical studies, this study has several limitations. One of the limitations of this study is the findings are most likely not generalizable to other sectors and other countries, since companies operating in different countries face different environmental regulations, cultural factors and a different manufacturing environment. Also, the fact that only public firms were used, means that the findings may not apply to smaller or private firms. Furthermore, “Date of Incorporation” from Refinitiv was used to calculate firm age, but this measure is not ideal, as it can differ from a firm’s actual founding date. As noted in the “Reliability and Validity” section, the incorporation year reported in Refinitiv can change due to name changes or mergers. For instance, Tesla changed its name from Tesla Motors to Tesla Inc. in 2017, while it was originally founded in 2003. Refinitiv reported 2017 as the incorporation year, despite the earlier founding date. This suggests that firm age may have been biased in some cases, meaning that some firms in the sample could in fact be older than

indicated.
Another limitation is that HHI was measured using only Compustat data. Since Compustat only includes public firms, private firms are excluded, which could affect the measured level of industry concentration. However, Laksmana and Yang (2015) note that large firms typically contribute the most to the HHI calculation, so excluding private, often smaller, firms may have minimal impact. An alternative used in some studies is the HHI calculated by the U.S. Census Bureau. However, a key disadvantage is that these are only available every five years. This made them unsuitable for this study, since the aim was to examine changes over consecutive years.

Based on the findings, several interesting directions could be recommended for future studies. First of all, this thesis focused on the environmental dimension of sustainability. Future studies could incorporate the social dimension. Moreover, as noted, very few studies have examined a moderator in the relationship between inventory leanness and environmental performance, which is concerning. Although the findings of this study show that leaner firms have better environmental performance, it is essential that managers know the specific conditions under which lean inventory practices yield the greatest benefits in terms of environmental performance, which will increase their willingness to implement and improve these practices. Hence, future studies could look at other moderators.
Lastly while this thesis demonstrates that leaner firms tend to have better environmental performance, the evidence for successful practical integration of lean and green practices is limited (Hallam & Contreras, 2016). Future research could therefore conduct case studies of firms implementing lean inventory strategies to better understand the mechanisms through which inventory leanness leads to improved environmental performance.

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**Appendix A: Distribution of Firms Over Subindustries**

| NAICS | n | Percentage |
|---|---|---|
| 311 | 23 | 4.44 |
| 312 | 19 | 3.67 |
| 315 | 8 | 1.54 |
| 321 | 6 | 1.16 |
| 322 | 11 | 2.12 |
| 324 | 18 | 3.47 |
| 325 | 91 | 17.57 |
| 326 | 7 | 1.35 |
| 327 | 9 | 1.74 |
| 331 | 22 | 4.25 |
| 332 | 23 | 4.44 |
| 333 | 57 | 11.00 |
| 334 | 118 | 22.78 |
| 335 | 19 | 3.67 |
| 336 | 58 | 11.20 |
| 337 | 6 | 1.16 |
| 339 | 23 | 4.44 |
| **Total** | **518** | **100%** |

## Appendix B: Assumption Tests

**Table B1**

*VIF Test*

```
. vif
```

| Variable | VIF | 1/VIF |
|---|---|---|
| RD_intensity | 1.22 | 0.822267 |
| Firm_size | 1.15 | 0.872176 |
| Capital_in~y | 1.15 | 0.872920 |
| Leverage | 1.11 | 0.898586 |
| HHI | 1.08 | 0.927620 |
| Firm_age | 1.08 | 0.928950 |
| ROA | 1.06 | 0.940083 |
| Inventory_~s | 1.06 | 0.945012 |
| Mean VIF | 1.11 | |

**B2**

*Wald Test*

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (518)  =     2497242.51
Prob > chi2 =          0.0000
```

**Appendix C: Robustness Check Results**

**Table C1**

*Alternative Measure for ELI*

| Variables | Baseline model | Moderator model |
|---|---|---|
| Lagged ELI | 2.309*** | 3.063*** |
| | (.734) | (1.015) |
| Capital intensity | 31.197*** | 32.278*** |
| | (8.323) | (8.37) |
| Firm age | 2.672*** | 2.695*** |
| | (.193) | (.194) |
| Firm size | 5.377*** | 5.412*** |
| | (1.429) | (1.428) |
| Leverage | -2.264 | -2.163 |
| | (3.582) | (3.565) |
| ROA | .596 | .625 |
| | (2.783) | (2.787) |
| RD intensity | 7.615 | 7.926 |
| | (8.547) | (8.564) |
| HHI | | -42.536 |
| | | (41.397) |
| Lagged ELI x HHI | | -14.728 |
| | | (14.915) |
| Constant | -122.801*** | -122.221*** |
| | (12.155) | (12.111) |
| Observations | 2590 | 2590 |
| $R^2$ | .299 | .3 |
| Year dummies | yes | yes |

*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*