# “Impact of research and development expenses on the profitability of assets: The case of textile and clothing industry in Portugal”


| | |
|---|---|
| **AUTHORS** | Ricardo de Moraes e Soares<br>Alexandre Morais Nunes<br>Paula Heliodoro<br>Vanda Martins |



| | |
|---|---|
| **ARTICLE INFO** | Ricardo de Moraes e Soares, Alexandre Morais Nunes, Paula Heliodoro and Vanda Martins (2024). Impact of research and development expenses on the profitability of assets: The case of textile and clothing industry in Portugal. *Problems and Perspectives in Management*, *22*(1), 702-715. doi:10.21511/ppm.22(1).2024.55 |
| **DOI** | http://dx.doi.org/10.21511/ppm.22(1).2024.55 |
| **RELEASED ON** | Thursday, 28 March 2024 |
| **RECEIVED ON** | Friday, 12 January 2024 |
| **ACCEPTED ON** | Tuesday, 12 March 2024 |





| | |
|---|---|
| **JOURNAL** | "Problems and Perspectives in Management" |
| **ISSN PRINT** | 1727-7051 |
| **ISSN ONLINE** | 1810-5467 |
| **PUBLISHER** | LLC “Consulting Publishing Company “Business Perspectives” |
| **FOUNDER** | LLC “Consulting Publishing Company “Business Perspectives” |

| NUMBER OF REFERENCES | NUMBER OF FIGURES | NUMBER OF TABLES |
|---|---|---|
| 48 | 0 | 2 |

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine

www.businessperspectives.org

**Ricardo de Moraes e Soares** (Portugal), **Alexandre Morais Nunes** (Portugal), **Paula Heliodoro** (Portugal), **Vanda Martins** (Portugal)

# IMPACT OF RESEARCH AND DEVELOPMENT EXPENSES ON THE PROFITABILITY OF ASSETS: THE CASE OF TEXTILE AND CLOTHING INDUSTRY IN PORTUGAL

## Abstract

The study aims to examine the financial efficiency of the textile and clothing industries in Portugal using official statistical data. The main objective is to assess the relationship between spending on research and development and return on assets. The study analyzes the performance of various subsectors of the textile and clothing industries, presenting the relationship between investments in research and development and the operating return on assets over various economic periods. The study adopted data envelopment analysis, classifying decision-making units based on average efficiency levels. The results highlight sectors of manufacture of textiles for technical and industrial use, manufacture of other textiles, production of outerwear, and manufacture of workwear as the most efficient. In contrast, sectors of manufacture of clothing and accessories, manufacture of knitwear, and leather clothing show lower levels of efficiency. From 2003 to 2022, the textile industry exhibited the highest levels of financial efficiency, with an above-average ratio between spending on research and development and return on assets. However, sectors of knitwear manufacturing and textile finishing have maintained a more or less constant level of financial efficiency. The analysis highlights the need for targeted interventions to increase the financial efficiency of different subsectors within the textile and clothing industries. It is evident that there are varying levels of financial efficiency across these sectors, and the need for benchmarking periods can help identify areas for improvement and set achievable goals.

**Keywords** clothing, efficiency, innovation, industry, manufacturing, textile

**JEL Classification** C67, L67, O14

**Received on:** 12th of January, 2024
**Accepted on:** 12th of March, 2024
**Published on:** 28th of March, 2024



Ricardo de Moraes e Soares, Ph.D. in Public Administration, Professor, Accounting and Finance Department, Higher School of Business Sciences, Polytechnic Institute of Setúbal, Portugal. (Corresponding author)

Alexandre Morais Nunes, Ph.D. in Public Administration, Professor, Public Administration Department, Higher Institute of Social and Political Sciences, University of Lisbon, Portugal.

Paula Heliodoro, Ph.D. in Management, Professor, Accounting and Finance Department, Higher School of Business Sciences, Polytechnic Institute of Setúbal, Portugal.

Vanda Martins, Specialist in Accounting and Taxation, Professor, Accounting and Finance Department, Higher School of Business Sciences, Polytechnic Institute of Setúbal, Portugal.



**Conflict of interest statement:**
Author(s) reported no conflict of interest

## INTRODUCTION

The financial efficiency of the textile and clothing sector in Portugal is currently a highly relevant area of research, particularly for industrial economics and business management. Studying the efficiency dynamics of the subsectors of the textile and clothing industry contributes to a theoretical understanding of economic activities. It can also aid the decision-making process of those involved in terms of drawing up and implementing public policies that are more beneficial to the development of this sector. The topic of financial efficiency is indeed a fundamental issue, especially when it comes to the allocation of scarce resources that are used by the various segments of the textile and clothing industry and how it relates to the performance and sustainability of companies (Elisa, 2023).

Research into the issue involves analyzing the multifaceted factors involved in efficiency, such as technological innovation, levels of in-



http://dx.doi.org/10.21511/ppm.22(1).2024.55

vestment in research and development (R&D), the types of production methods adopted, and market dynamics (Liu & Xia, 2018). It is interesting to analyze the implications of financial efficiency on the economic and political choices of companies and decision-makers. Examining possible relationships between efficiency, competitiveness, and sustainability of resource allocation and providing information both at the organizational and political levels are vital. Analyzing efficiency in the textile and clothing industries aims to generate knowledge that can strengthen theoretical understanding and practical results in industrial economics and business management.

## 1. LITERATURE REVIEW AND HYPOTHESES

In the European Union, the textile and clothing industry constitutes approximately 4.0% of production and 7.0% of employment in manufacturing. In Portugal, similar to the EU, the industry faces challenges such as global competition (European Commission, 2003), low innovation (Montenegro, 2011), and low research levels (Sousa, 2020). Maintaining employment and production levels (Ferreira, 2018), ensuring quality (Cardoso & Ferreira, 2013), adding value (Pereira, 2021), acquiring new skills (Merle & Fermam, 2023), and pursuing modernization (Nikam, 2003) are key priorities for the industry.

The abolition of import quotas in 2005 instigated a need in the Portuguese sector to adapt to new circumstances and accept the rules of the international market (Silva, 2013). The European textile and clothing industry, primarily comprising small and medium-sized companies, holds a value exceeding 200 billion euros. In Portugal, its significance is underlined by tradition (Nogueira, 2020), empirical knowledge (Santos, 2011), quality, and creativity (Proença et al., 2008).

The Portuguese textile and clothing industry, pivotal for the country's economy, generates income through exports and internal trade. Renowned for product quality, particularly textiles (Puime-Guillén et al., 2021), Portugal exports to global markets, with a focus on European countries (Nagy, 1999). Quality and innovation have significantly enhanced the competitiveness of the industry (Montagna & Carvalho, 2018), contributing to its ability to offer diverse opportunities and economic growth. In pursuit of innovation, the Portuguese textile industry has embraced advanced technologies and sustainable practices (Costa, 2022). Faced with global competition and evolving consumption patterns, industry reforms, new practices, and increased research and development spending are imperative (Basto et al., 2021).

Jajri and Ismail (2006) explored the relationship between new technologies and the growth of Malaysia's manufacturing sector. Their analysis concentrated on the sector's evolution in technical efficiency. The results suggest that, on average, the food, wood, chemicals, and iron products sectors showcase the highest technical efficiency. In contrast, the food and textiles sectors exhibit the lowest efficiency in resource allocation, indicating potential areas for improvement in these industries.

Khalil (2011) scrutinized the relative efficiency of Pakistan's textile sector using data envelopment analysis (DEA). The findings revealed subpar technical efficiency across all production units, necessitating the adoption of more efficient measures. The study concluded that addressing the rising pollution levels associated with textile production processes is imperative for the sustainable development.

Rakhmawan et al. (2012) explored the efficiency relationship between performance indicators and productivity in the textile industry through data envelopment analysis. The sector exhibited a 40% efficiency level and an average productivity growth of 2.40%. The study inferred that enhancing efficiency distinctly and positively influences the overall productivity of the textile sector.

In assessing the technical efficiency of the Chinese manufacturing industry in relation to energy expenditure, Fang et al. (2013) employed the DEA model. The study identified the textile sector as having the highest technical efficiency. In comparison, the machinery and electronics manufacturing industry exhibited a notable increase in efficiency when environmental variables were not considered.

Pérez et al. (2017) evaluated the technical efficiency of the Chilean textile and clothing industry. They revealed diverse efficiency levels related to energy expenditure, greenhouse gas emissions, and geographical location. The study, employing DEA analysis, identified industries in Coquimbo, La Araucania, and Aysen as the most efficient, while those in Tarapaca, Antofagasta, and Biobio exhibited the lowest technical efficiency.

Li and Tsai (2018) examined the efficiency of the textile/clothing pipeline, spanning from the production of fibers, fabrics, and clothing to end consumers. They delved into the sector's cost calculation processes and the retail capacity of companies. The findings underscored that efficiency levels are notably influenced by these factors.

Financial efficiency in the textile and clothing industries depends on multiple factors, including training expenses, education level, capital costs, company size, wages, innovation, technology, and research and development spending (Fahmy-Abdullah et al., 2018). The analysis of 1,010 companies in Malaysia revealed a high level of technical efficiency. The study suggests that the textile industry should enhance its approach to high-tech production by fostering stronger connections between production, research, education, motivation, and wage levels.

Sueyoshi and Goto (2019) highlighted the textile and clothing industry's financial efficiency by considering the interaction between operational and environmental outcomes. The industry in Japan exhibited high proficiency in resource allocation and energy management, emphasizing the substantial potential for efficiency improvement through increased investments in innovation and emerging technologies.

Industry efficiency assessment involves analyzing employee numbers, optimizing working hours through increased assets, evaluating unproductive machines, and adjusting raw material consumption (Sudri et al., 2019). Findings indicate variable technical efficiency among production units.

Popker and Raju (2020) explored the financial efficiency of the textile and clothing industries by examining the link between financial performance and production levels. Simultaneously applying Z-Score and data envelopment analysis (DEA) methodologies, the results indicated variable and disparate efficiency in the relationship between financial performance and production levels.

Du et al. (2022) assessed the impact of innovation on manufacturing industry efficiency by exploring the relationship between innovation and development expenditure, personnel expenditure, revenue from sales of new products, and the number of patent applications. Findings indicated low levels of innovation and technological evolution, resulting in overall low technical efficiency. However, increased investment in innovation, particularly in cities like Xianning, Xiantao, and Tianmen, is identified as a means to enhance the efficiency of the manufacturing sector.

Darji and Dahiya (2023) evaluated the operational efficiency of textile production units in India by examining the relationship between performance indicators and production factors. Findings indicated notably low operational performance, suggesting that companies should consider reducing the size of production factors to enhance efficiency.

Regarding assessing financial efficiency, Zenzerovic et al. (2023) focused on the relationship between return on assets and human capital efficiency. The objective was to categorize technical efficiency based on accounting indicators. Results indicated that service sectors outperformed industrial ones due to a more efficient relationship between EBITDA and human capital efficiency. At a sectoral level, wholesale trade, retail, repair, information, communication, and education sectors demonstrated higher technical efficiency, while construction, water-related activities, sanitation, waste management, remediation, accommodation, and catering displayed lower efficiency.

Efficiency is characterized by the ability to minimize resource waste, achieving optimal results with the least amount of resources. Efficiency is measured by comparing what was produced to what could have been produced with the same resources (Mello et al., 2005). It mathematically represents the relationship between outputs (desired objectives) and inputs (allocated resources), emphasizing the optimal utilization of resources to attain specified goals.


http://dx.doi.org/10.21511/ppm.22(1).2024.55

When analyzing efficiency, it is vital not to conflate it with effectiveness (Mello et al., 2005). Effectiveness pertains to what is produced, disregarding the resources allocated. In essence, efficiency optimizes resources for results, while effectiveness concentrates on results without considering the resources invested in achieving the objectives.

Despite the small number of studies on the subject under analysis, this study aims to deepen the debate on innovation in the textile and clothing sectors and analyze the possible levels of efficiency of Portuguese companies, providing a new perspective on the performance of investments and, above all, their profitability. The paper explores the efficiency of Portugal's textile and clothing sectors from 2003 to 2022, focusing on the correlation between R&D spending and the profitability of companies' assets. The following hypotheses are established:

*H1: Research and development (R&D) costs do not show a relationship with the return on assets for all financial years, with financial efficiency equal to one ($e\lambda = 0$).*

*H2: Research and development (R&D) costs show some level of relationship with the return on assets for all financial years, with financial efficiency equal to one ($0 > e\lambda < 1$).*

*H3: Research and development (R&D) costs show a perfect relationship with the return on assets for all financial years, with financial efficiency equal to one ($e\lambda = 1$).*

## 2. METHODS

This case study applies statistical data relating to the financial statements of companies in the textile and clothing sector of Portugal. Data are available on the official websites of the Bank of Portugal and the National Statistics Institute for 2003–2022.

The data were organized into two sectors of economic activity (I: Textiles and II: Clothing) and then into eighteen subsectors (I.1: Preparation and spinning of textile fibers; I.2: Textile weaving; I.3: Textile finishing; I.4: Manufacture of knitted fabrics; I.5: Manufacture of made-up textile articles; I.6: Carpet and rug manufacturing; I.7: Manufacture of nonwovens and related products; I.8: Manufacture of nonwovens and related products; I.9: Manufacture of textiles for technical and industrial use; I.10: Manufacture of other textiles; and II.1: Leather garment manufacturing; II.2: Making work clothes; II.3: Manufacture of other outerwear; II.4: Underwear manufacturing; II.5: Manufacture of other clothing articles and accessories; II.6: Manufacture of fur articles; II.7: Manufacture of knitted and crocheted hosiery; II.8: Manufacture of other knitted and crocheted garments). The weights of the inputs (R&D spending and gross value added) and their relationship with the outputs (operating return on assets, economic return on assets, and net return on assets) were calculated for each of the sectors.

The study applied nonparametric DEA approach, and no explicit relationship was established between inputs and outputs. The ability to transform inputs into outputs was measured as an efficiency index, with the subsector being more efficient (Ar & Baki, 2007) in a given year, the more outputs it obtains (results) with the fewest possible inputs (Sangeetha, 2020).

For this study, efficiency varies between zero (inefficient) and one (efficient) and is obtained through the distance between the inefficient DMU and the efficient DMU (Shewell & Migiro, 2016), which translates into input surpluses or output deficits. The input-oriented model and efficiency are described as follows:

$$Efficiency = \frac{\sum_{r=1}^{s} U_r Y_r}{\sum_{i=1}^{m} V_i X_i}, \quad (1)$$

where $U_r$ – weight of financial returns on assets; $Y_r$ – the level of financial returns on assets; $V_i$ – weight of efficiency of research and development spending; $X_i$ – the level of efficiency of research and development spending; $s$ – number of sectors related to financial returns on assets; and $m$ – number of sectors related to efficiency of research and development spending.

The procedure measures the efficiency of resource utilization (financial returns on assets and research and development expenditure) in each of

the subsectors of the textile and clothing industry. The numerator signifies the weighted total financial return on assets in all subsectors, while the denominator represents the weighted total efficiency of research and development expenditure in all subsectors.

Efficiency is calculated by dividing the weighted total return on assets by the weighted total efficiency of research and development expenditures. The results provide insights into how effectively resources are being used to generate financial returns in relation to the research and development expenditures of the various subsectors, taking into account the model's constraints and limitations (Barbosa & Fuchigami, 2018).

The study calculations were carried out using Excel software. The DEA methodology was selected for analyzing the efficiency of the textile and clothing industry due to its flexibility in selecting inputs and outputs and model's orientation. The research preference is to maintain inputs (level of expenditure on innovation) and increase outputs (results through the efficiency of net fixed applications).

## 3. RESULTS

The results shed light on the dynamic interplay between R&D investments and operational performance across different economic periods (Table 1).

For DMU I.1, encompassing textile fiber preparation and spinning, the average participation of R&D spending in efficiency results was 14.36%. Notably, during certain economic periods (2003, 2006–2010, 2013, and 2019–2021), R&D spending exhibited negligible influence on operational, economic, and net returns on invested assets ($e\lambda = 0$). In contrast, 2015 and 2017 marked efficient periods, indicating a significant positive impact of R&D spending on overall efficiency ($e\lambda = 1$).

In the textile weaving sector (DMU I.2), the average efficiency level was 31.22%, indicating inefficiency. Zero contribution of R&D spending to efficiency was observed in 2008, 2009, 2011, and 2012 ($e\lambda = 0$), suggesting that during these years, R&D spending did not significantly contribute to the sector's operational, economic, and net returns on assets. The results for 2003 to 2007, 2010, 2013 to 2016, and 2018 to 2022 indicated technical inefficiency ($0 > e\lambda < 1$). However, in 2017, the relationship between R&D spending and return on assets was efficient, portraying a positive impact of R&D investments on technical efficiency ($e\lambda = 1$).

Moving on to textile finishing (DMU I.3), the results indicated an average efficiency level of 41.43%, signifying inefficiency. In specific years (2006, 2008, 2009, 2011, and 2012), the relationship between R&D spending and return on assets was zero ($e\lambda = 0$). Conversely, technical inefficiency was evident ($0 > e\lambda < 1$) for 2003 to 2005, 2007, 2010, 2013 to 2019, 2021, and 2022. However, in 2020, the data indicated an efficient relationship between R&D spending and return on assets ($e\lambda = 1$).

In the manufacturing of made-up textile articles (DMU I.5), the average efficiency level was 45.46%, indicating inefficiency in allocating R&D spending in relation to the return provided by assets. In 2011 and 2012, the relationship between the return on assets and R&D spending was zero ($e\lambda = 0$), suggesting that R&D spending did not lead to improved levels of return on investment. For 2003 to 2010, 2013 to 2020, and 2022, inefficiency was observed ($0 > e\lambda < 1$). However, for 2021, a technically efficient relationship between R&D spending and return on assets was observed ($e\lambda = 1$).

Analyzing the manufacturing of rope and nets (DMU I.7), the data showed an average technical efficiency of 54.98%, indicating inefficiency in the activity. In 2003, 2004, 2006 to 2008, and 2010 to 2019, technical inefficiency was observed ($0 > e\lambda < 1$). However, 2005, 2009, 2020, and 2022 were technically efficient ($e\lambda = 1$), signifying that R&D spending positively contributed to the efficiency of the sector's return on assets.

In the manufacturing of non-woven fabrics and articles (DMU I.8), the average technical efficiency level was 61.31%, indicating inefficiency in allocating R&D spending. In 2003, 2004, 2006 to 2014, 2016, 2018, 2019, and 2022, technical inefficiency was observed ($0 > e\lambda < 1$). Conversely, 2005, 2015, 2017, 2020, and 2021 were technically efficient


http://dx.doi.org/10.21511/ppm.22(1).2024.55

(eλ = 1), designating these periods as benchmark DMUs with an efficient relationship between R&D spending and return on invested assets.

Moving to technical and industrial textile manufacturing (DMU I.9), the average technical efficiency level was 74.81%, indicating inefficiency. 2003 and 2004, 2006 to 2014, 2016 and 2017, 2019, and 2022 were technically inefficient (0 > eλ < 1). However, 2005, 2015, and 2018 were technically efficient (eλ = 1), designating these years as benchmark periods.

For the manufacturing of other textile sectors (DMU I.10), the results indicated an average efficiency level of 65.96%, portraying inefficiency. Between 2003 and 2016 and between 2018 and 2021, the relationship between R&D spending and the return on invested assets was technically inefficient (eλ < 1). Conversely, the results for the 2017 and 2018 economic periods suggested technical efficiency (eλ = 1).

Moving to leather garment manufacturing (DMU II.1), the data suggested an average level of technical efficiency in the ratio of R&D spending to return on assets of 19.58%, indicating inefficiency. 2003–2010, 2013, 2019, 2021, and 2021 showed zero technical efficiency (eλ = 0). Conversely, for 2015 to 2018, the data suggested inefficient technical efficiency between R&D spending and return on assets (0 > eλ < 1). For 2016, 2017, and 2021, the relationship between R&D spending and return on assets was technically efficient (eλ = 1).

For the manufacturing of work clothes (DMU II.2), the data pointed to an average technical efficiency of 61.77%, indicating inefficiency. 2003 to 2013, 2015 to 2017, 2019, 2021, and 2022 showed an inefficient relationship between R&D spending and return on assets (0 > eλ < 1). Meanwhile, the financial years 2014, 2018, and 2020 were efficient periods (eλ = 1), designating these periods as benchmarking intervals in which R&D spending efficiently influenced the return on assets.

Analyzing the manufacturing of other outerwear (DMU II.3), the data suggested an average technical efficiency of 63.19% (inefficient). In 2003 to 2014, 2016, 2017, and 2019 to 2021, there was technical inefficiency in the allocation of spending on research and development (0 > eλ < 1). 2015, 2018, and 2022 corresponded to technically efficient intervals (eλ = 1), where the relationship between R&D spending and asset profitability was efficient.

For the underwear manufacturing sector (DMU II.4), the results showed an average technical efficiency of 36.90%, indicating inefficiency. In 2009 and 2012, there was zero efficiency (eλ = 0), while in 2003–2008, 2010, 2011, and 2013–2020, there was inefficient technical efficiency between R&D spending and return on assets (0 > eλ < 1). However, the 2021 and 2022 results suggested that both periods were technically efficient (eλ = 1), designating these intervals as benchmarking periods where R&D spending contributed efficiently to the return on assets.

In the manufacturing of other articles and clothing accessories (DMU II.5), the results indicated an average technical efficiency level of 28.82%, making it the fourth-most inefficient sector in terms of the relationship between R&D spending and return on assets. 2008, 2012, and 2013 were, according to the model, years of zero efficiency (eλ = 0). In other words, there was no relationship between R&D spending and investment returns. 2003 to 2007, 2009 to 2011, and 2014 to 2021 corresponded to periods of technical inefficiency (0 > eλ < 1). 2022 was a reference period, i.e., the relationship between R&D spending and the return on assets was technically efficient (eλ = 1).

For the manufacturing of fur articles (DMU II.6), an average technical efficiency of 29.87% was found, indicating inefficiency. 2003, 2007–2009, 2011, and 2022 were periods of zero efficiency (eλ = 0). The economic years 2004 to 2006, 2010, 2012, 2013, and 2015 to 2020 were technically inefficient periods (0 > eλ < 1), as the relationship between R&D spending and return on assets was inefficient. The years 2014 and 2021, on the other hand, were technically efficient (eλ = 1) and represented reference periods.

For the manufacturing of knitted and crocheted hosiery (DMU II.7), the average technical efficiency of R&D spending was 23.77%, indicating an inefficient sector. For 2003, 2006 to 2008, 2010, 2015, 2018 to 2020, zero technical efficiency was found (eλ = 0). In 2004, 2005, 2011, 2012, 2014, 2016,

2017, 2021, and 2022, the results suggested periods of technical inefficiency ($0 > e\lambda < 1$). On the other hand, 2009 and 2013 reflected moments of technical efficiency in the allocation of R&D spending in relation to the profitability of the sector's assets ($e\lambda = 1$).

For the manufacturing of other knitted garments (DMU II.8), the results suggested a level of technical efficiency, on average, in the allocation of R&D spending for the purposes of return on assets of 37.25%, indicating inefficiency. For 2007 to 2010, zero technical efficiency was found in the sector ($e\lambda = 0$). From 2003 to 2006, 2011 to 2015, and 2017 to 2021, the results indicated a relationship between R&D spending and return on assets that was inefficient ($0 > e\lambda < 1$). While 2016 and 2022 reflected periods of technical efficiency ($e\lambda = 1$), it was observed that R&D spending efficiently contributed to the return on assets.

In the textile industry, the period with the highest level of technical efficiency was 2017 (82.76%), and the lowest was 2011 (15.47%). For the clothing industry, the data indicated that the period with the highest level of technical efficiency in the allocation of R&D spending was 2021 (73.11%), and the lowest efficiency was in 2010 (7.67%).

The DEA methodology serves to rank DMUs by average efficiency levels. Table 2 presents the estimated technical efficiency for each subsector, offering a clear classification based on performance.

The DEA model analysis highlights the textile industry as a leader in technical efficiency, excelling in optimizing the correlation between R&D spending and returns on invested assets. Textile subsectors consistently demonstrate superior financial performance, evidenced by in high return on assets (ROA), return on equity (ROE), and return on liabilities and assets (RLA). This underscores the industry's prowess in leveraging innovation for financial success and positions it as a benchmark for effective resource allocation and operational efficiency.

Table 2 highlights key findings, revealing that activities with the highest average technical efficiency include the manufacture of textiles for technical and industrial use (DMU I.9), the manufacture of other textiles (DMU I.10), the manufacture of other outerwear (DMU II.3), and the manufacture of workwear (DMU II.2). Conversely, sectors with lower average technical efficiency levels encompass the manufacture of other wearing apparel (DMU II.5), knitted and crocheted hosiery (DMU II.7), leather goods (DMU II.1), and the preparation and spinning of textile fibers (DMU I.1). These sectors exhibit lower R&D expenditure levels, affecting returns on assets employed in production.

Certain sectors, including the manufacture of knitted fabrics (DMU I.4), textile finishing (DMU I.3), the manufacture of carpets and rugs (DMU I.6), and the manufacture of other knitted garments (DMU II.8), consistently maintained technical efficiency over the 2003–2022 period. However, despite highlighting a degree of technical efficiency, these sectors remain heavily influenced by external factors such as market evolution, pricing dynamics, and consumer preferences, underscoring the multifaceted nature of industry performance beyond innovation alone. This nuanced understanding is crucial for industry stakeholders to navigate dynamic market landscapes and make informed strategic decisions.

The results on the average efficiency of the textile and clothing industry sub-sectors (Table 2) show that hypothesis 2 is accepted ($0 > e\lambda < 1$), while hypotheses 1 ($e\lambda = 0$) and 3 are rejected ($e\lambda = 1$). The results suggest that there is some level of relationship between R&D costs and return on assets, i.e., they have contributed in some way to the efficiency of the return on assets of the sub-sectors of the Portuguese textile and clothing industry.

Throughout the series, it can be seen, by industry sub-sector and economic year (Table 1), that the efficiency results are variable, which allows the hypotheses to be accepted and rejected simultaneously. In 2003, hypothesis 1 was accepted in 4 DMUs, while hypothesis 2 was accepted in 14 DMUs. Hypothesis 3 was rejected. In 2004, hypothesis 1 was accepted in 1 DMU, and hypothesis 2 was accepted in 17 DMUs. Hypothesis 3 was rejected for all DMUs. As for 2005, hypothesis 1 was accepted in 1 DMU, and hypothesis 2 was accepted in 14 DMUs. The hypothesis was accepted in 3 DMUs. In 2006, hypothesis 1 was


http://dx.doi.org/10.21511/ppm.22(1).2024.55

**Table 1.** Results of the DEA model in the textile and clothing sector for the period 2003–2022

| DMU | Years | | | | | | | | | | | | | | | | | | | Average DMU |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | |
| **Textile industry** | | | | | | | | | | | | | | | | | | | | | |
| I.1 | 0.00% | 1.86% | 3.34% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 2.56% | 5.36% | 0.00% | 23.30% | 100.00% | 7.49% | 100.00% | 13.06% | 0.00% | 0.00% | 0.00% | 30.24% | 14.36% |
| I.2 | 14.72% | 20.36% | 40.64% | 29.24% | 10.81% | 0.00% | 0.00% | 4.73% | 0.00% | 0.00% | 25.20% | 33.72% | 34.73% | 44.79% | 100.00% | 60.36% | 42.66% | 35.40% | 75.41% | 51.67% | 31.22% |
| I.3 | 10.92% | 41.03% | 77.46% | 0.00% | 22.84% | 0.00% | 0.00% | 13.68% | 0.00% | 0.00% | 63.19% | 82.63% | 48.79% | 71.94% | 90.28% | 53.50% | 55.73% | 100.00% | 61.61% | 34.91% | 41.43% |
| I.4 | 18.67% | 15.98% | 31.92% | 7.29% | 35.73% | 18.25% | 5.70% | 18.19% | 20.70% | 17.44% | 55.86% | 54.10% | 62.43% | 80.01% | 79.12% | 56.62% | 44.20% | 44.69% | 100.00% | 100.00% | 43.35% |
| I.5 | 51.63% | 34.66% | 70.03% | 84.42% | 81.22% | 29.77% | 40.92% | 35.26% | 0.00% | 0.00% | 0.84% | 22.10% | 40.35% | 44.43% | 61.55% | 45.43% | 35.66% | 38.12% | 100.00% | 92.85% | 45.46% |
| I.6 | 17.98% | 27.81% | 62.01% | 16.53% | 25.85% | 0.00% | 0.00% | 20.12% | 0.00% | 0.00% | 17.71% | 100.00% | 44.83% | 30.48% | 67.19% | 45.72% | 76.76% | 29.86% | 72.04% | 100.00% | 37.74% |
| I.7 | 40.58% | 52.58% | 100.00% | 17.17% | 71.39% | 24.03% | 100.00% | 49.16% | 22.61% | 15.40% | 35.17% | 42.04% | 64.17% | 54.51% | 43.16% | 21.00% | 46.63% | 100.00% | 100.00% | 100.00% | 54.98% |
| I.8 | 34.01% | 55.98% | 100.00% | 9.41% | 32.59% | 18.40% | 10.99% | 89.71% | 41.25% | 65.29% | 15.53% | 69.81% | 100.00% | 88.38% | 100.00% | 81.45% | 45.86% | 100.00% | 100.00% | 67.45% | 61.31% |
| I.9 | 55.59% | 53.66% | 100.00% | 74.47% | 69.24% | 44.03% | 46.48% | 67.90% | 56.63% | 46.20% | 62.57% | 88.08% | 100.00% | 97.60% | 86.32% | 100.00% | 97.05% | 72.30% | 93.88% | 84.22% | 74.81% |
| I.10 | 61.46% | 54.10% | 96.30% | 69.99% | 62.92% | 69.73% | 42.46% | 40.25% | 10.96% | 20.19% | 58.60% | 58.91% | 59.57% | 80.44% | 100.00% | 93.99% | 95.99% | 64.65% | 78.76% | 100.00% | 65.96% |
| Average | 30.56% | 35.80% | 68.17% | 30.85% | 41.26% | 20.42% | 24.66% | 33.90% | 15.47% | 16.99% | 33.47% | 57.47% | 65.49% | 60.01% | 82.76% | 57.11% | 54.05% | 58.50% | 78.17% | 76.13% | – |
| **Clothing industry** | | | | | | | | | | | | | | | | | | | | | |
| II.1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 15.12% | 100.00% | 100.00% | 76.42% | 0.00% | 0.00% | 100.00% | 0.00% | 19.58% |
| II.2 | 37.63% | 33.02% | 33.22% | 40.28% | 36.08% | 79.98% | 67.48% | 26.34% | 45.84% | 26.69% | 68.06% | 100.00% | 79.59% | 76.88% | 89.47% | 100.00% | 73.04% | 100.00% | 55.17% | 66.54% | 61.77% |
| II.3 | 58.93% | 53.19% | 61.20% | 91.77% | 55.62% | 48.43% | 18.99% | 8.97% | 26.24% | 32.11% | 71.93% | 88.07% | 100.00% | 65.84% | 86.83% | 100.00% | 68.81% | 52.12% | 74.80% | 100.00% | 63.19% |
| II.4 | 27.64% | 22.59% | 26.67% | 25.38% | 31.99% | 36.88% | 0.00% | 15.73% | 0.59% | 0.00% | 25.23% | 27.47% | 49.05% | 37.26% | 53.65% | 68.78% | 46.25% | 42.86% | 100.00% | 100.00% | 36.90% |
| II.5 | 16.08% | 23.89% | 21.82% | 33.44% | 20.34% | 0.00% | 10.27% | 5.97% | 6.35% | 0.00% | 0.00% | 23.92% | 32.19% | 48.06% | 51.38% | 38.80% | 40.35% | 45.83% | 57.79% | 100.00% | 28.82% |
| II.6 | 0.00% | 19.85% | 31.17% | 3.13% | 0.00% | 0.00% | 0.00% | 4.37% | 0.00% | 12.17% | 49.95% | 100.00% | 73.72% | 20.01% | 11.99% | 75.91% | 50.81% | 44.35% | 100.00% | 0.00% | 29.87% |
| II.7 | 0.00% | 3.53% | 7.24% | 0.00% | 0.00% | 0.00% | 100.00% | 0.00% | 24.79% | 8.91% | 100.00% | 23.21% | 0.00% | 51.29% | 9.31% | 0.00% | 0.00% | 0.00% | 59.81% | 87.34% | 23.77% |
| II.8 | 6.50% | 24.61% | 31.93% | 5.46% | 0.00% | 0.00% | 0.00% | 0.00% | 32.70% | 3.56% | 41.30% | 60.48% | 74.20% | 100.00% | 78.87% | 90.51% | 55.56% | 2.02% | 37.27% | 100.00% | 37.25% |
| Average | 18.35% | 22.59% | 26.66% | 24.93% | 18.00% | 20.66% | 24.59% | 7.67% | 17.06% | 10.43% | 44.56% | 52.89% | 52.98% | 62.42% | 60.19% | 68.80% | 41.85% | 35.90% | 73.11% | 69.24% | – |

**Table 2.** Average efficiency ranking for the textile and clothing industry for the period 2003–2022

| Rank | Economic activities | Average |
|---|---|---|
| 1 | I.9-Manufacture of textiles for technical and industrial use | 74.81% |
| 2 | I.10-Manufacture of other textiles | 65.96% |
| 3 | II.3-Manufacture of other outerwear | 63.19% |
| 4 | II.2-Making work clothes | 61.77% |
| 5 | I.8-Manufacture of nonwovens and articles made from nonwovens | 61.31% |
| 6 | I.7-Manufacture of rope and netting | 54.98% |
| 7 | I.5-Manufacture of made-up textile articles | 45.46% |
| 8 | I.4-Manufacture of knitted fabrics | 43.35% |
| 9 | I.3-Textile finishing | 41.43% |
| 10 | I.6-Carpet and rug manufacturing | 37.74% |
| 11 | II.8-Manufacture of other knitted and crocheted garments | 37.25% |
| 12 | II.4-Underwear manufacturing | 36.90% |
| 13 | I.2-Textile weaving | 31.22% |
| 14 | II.6-Manufacture of fur articles | 29.87% |
| 15 | II.5-Manufacture of other clothing articles and accessories | 28.82% |
| 16 | II.7-Manufacture of knitted and crocheted hosiery | 23.77% |
| 17 | II.1-Leather garment manufacturing | 19.58% |
| 18 | I.1-Preparation and spinning of textile fibers | 14.36% |
| Total average efficiency | | **42.88%** |

accepted in 4 DMUs, while hypothesis 2 was accepted in 14 DMUs. Hypothesis 3 was rejected. In 2007, hypothesis 1 was accepted in 5 DMUs, and hypothesis 2 was accepted in 13 DMUs. Hypothesis 3 was rejected.

As for 2008, hypothesis 1 was accepted in 9 DMUs, and hypothesis 2 was accepted in 9 DMUs. Hypothesis 3 was rejected. In 2009, hypothesis 1 was accepted in 8 DMUs, hypothesis 2 in 8 DMUs, and hypothesis 3 in 2 DMUs. In 2010, hypothesis 1 was accepted in 4 DMUs and hypothesis 2 in 14 DMUs. Hypothesis 3 was rejected. In 2011, hypothesis 1 was accepted in 6 DMUs, and hypothesis 2 was accepted in 12 DMUs. Hypothesis 3 was rejected. In 2012, hypothesis 1 was accepted in 7 DMUs and hypothesis 2 in 11 DMUs. Hypothesis 3 is rejected.

In 2013, hypothesis 1 was accepted in 3 DMUs, hypothesis 2 in 14 DMUs, and hypothesis 3 in 1. In 2014, hypothesis 1 was accepted in 1 DMU, hypothesis 2 was accepted in 14 DMUs, and hypothesis 3 was accepted in 3 DMUs. In 2015, hypothesis 1 was accepted in 1 DMU, hypothesis 2 in 13 DMUs, and hypothesis 3 in 4 DMUs. For 2016, hypothesis 1 was rejected, hypothesis 2 was accepted in 16 DMUs, and hypothesis 3 was accepted in 2 DMUs. For 2017, hypothesis 1 was rejected, hypothesis 2 was accepted in 13 DMUs, and hypothesis 3 was accepted in 5 DMUs.

For 2018, hypothesis 1 was accepted in 1 DMU, hypothesis 2 was accepted in 14 DMUs, and hypothesis 3 was accepted in 3 DMUs. In 2019, hypothesis 1 was accepted in 3 DMUs, and hypothesis 2 was accepted in 15 DMUs. Hypothesis 3 was rejected. In 2020, hypothesis 1 is accepted in 3 DMUs, hypothesis 2 was accepted in 11 DMUs, and hypothesis 3 in 4 DMUs. In 2021, hypothesis 1 was accepted in 1 DMU, hypothesis 2 in 10 DMUs, and hypothesis 3 in 7 DMUs. Finally, in 2022, hypothesis 1 was accepted in 2 DMUs, hypothesis 2 was accepted in 8 DMUs, and hypothesis 3 was accepted in 8 DMUs.

This analysis provides a detailed overview of the technical efficiency levels within various subsectors of the textile and clothing industries, emphasizing the relationship between R&D spending and return on assets. The findings reveal fluctuating efficiency levels across different economic periods, highlighting areas of inefficiency and opportunities for improvement. Understanding these dynamics is crucial for industry stakeholders, policymakers, and investigators to develop targeted strategies, enhance overall industry performance, and foster sustainable growth.

## 4. DISCUSSION

The Portuguese textile and clothing industry is a crucial sector of the national economy, integrating tradition, artisanship, and innovation. Over


http://dx.doi.org/10.21511/ppm.22(1).2024.55

the years, the sector has faced a number of challenges, including international competition, the need to modernize production technology, and changing consumer preferences. The results of the study attest to the principle that Portuguese companies face various challenges and are in line with the conclusions of the aforementioned studies, especially as they provide a perspective on the efficiency and performance of the textile and clothing industry in Portugal.

The results indicate the efficiency levels of the textile and clothing subsectors in a new international context. Due to their low efficiency, it is essential to understand and increase the financial efficiency levels of companies. The imperative is to maintain competitiveness and, at the same time, give new impetus to the sector's growth. Like Jajri and Ismail (2006), the results attest to the low financial efficiency of the Portuguese industry. On the other hand, the results also align with Khalil's (2011) observations, which emphasize the inefficiency of production units and the need to adopt innovative and efficient production tools.

Research spending in the manufacturing industry has been the subject of much debate in Portugal in recent years. Academia recognizes the importance of the topic and the need to assess and discuss the levels of gains made by the various economic sectors (Rai, 2013). However, the results reveal the presence of low levels of investment in research and development, reflected in low levels of efficiency and operational performance. The data are consistent with Rakhmawan et al. (2012), who investigated the effectiveness of performance indicators and how they affected productivity in the textile industry. In the Portuguese context, the level of financial efficiency of allocated assets varies between 14.36 and 74.81%, depending on the subsector of the textile and clothing industry, while the study indicated the efficiency of the textile industry was 40.0%.

The theory goes that Portuguese industrialization was late (Fortuna, 1993) and was mainly based on foreign models (Marques, 2023). However, although the adoption of foreign models led to the so-called "economic miracle," the results were temporary, unstable (Gonçalves & Caraça, 1986), and based on continued energy dependence (Neto, 1991). As a result, like other countries (Nassif, 2023), the Portuguese industry was forced into sudden technological innovation and modernization (CIP, 2017). For Darji and Dahiya (2023), the textile and clothing sector has always shown low levels of modernization and efficiency regardless of the model adopted. The results of this study show that the financial efficiency of the Portuguese textile and clothing industry is clearly low, which means that it needs to invest heavily in order to modernize. In addition, the industry needs to adopt innovative procedures and research methodologies to acquire new knowledge. As Darji and Dahiya (2023) discovered, the existing technological levels in the textile sector represent challenges for achieving better efficiency results.

One of the sector's problems stems from the need to increase the current levels of efficiency of research and development (R&D) spending in relation to the profitability of investments. According to the doctrine, industrial development is truly related to the ability of companies to adopt new, more efficient production technologies that foster the competitiveness of manufacturing companies and increase financial results (ATP, 2019). According to the estimated results, which are in line with the conclusions of Fang et al. (2013) and Li and Tsai (2018), there is a positive correlation between increased innovation and the financial efficiency of the production process. On the other hand, there is greater financial efficiency in the textile sector compared to the clothing sector. The higher the quality of research investments, the higher the levels of financial efficiency produced.

The technological modernization of the Portuguese textile and clothing industry requires new investments in strategic assets, such as the purchase of patents and intellectual property (WIPO, 2005) and obtaining new competitive advantages (Proença, 2018). One of the challenges facing the textile and clothing subsectors is that it is difficult for companies to keep up with technology. Since some of the subsectors analyzed have zero efficiency levels, this underlines the economic imperative of increasing efficiency levels in allocating available resources, both financially and in terms of sustainability, as highlighted by Sueyoshi and Goto (2019).

Currently, financial efficiency levels cannot and should not be limited to economic agents' ability to increase tax efficiency levels through local tax benefits (Soares & Pinheiro, 2023); efficiency must also be

measured in terms of investment decisions, whether in assets or research and development (R&D). In line with Fahmy-Abdullah et al. (2018) and Du et al. (2022), the levels of R&D spending on financial efficiency are low and companies should promote a closer relationship between production and research. Policymakers need to encourage companies to invest in innovation in order to improve efficiency and increase the return on invested assets.

As far as the hypotheses are concerned, the results mainly point to the validation of hypothesis 2, since all subsectors of the textile and clothing industry do not exhibit a relationship between the efficiency of R&D spending and return on assets for all years of technical efficiency equal to one. However, the relationship between innovation and efficiency should be extended to other activities to understand the situation of economic agents, since they are not isolated in the marketplace.

A pertinent future research question involves analyzing the impact of efficiency on the circular economy and sustainability in line with current political agendas. To this end, it is necessary to analyze the efficiency of circular models and strategies for extending the lifespan of products. The assessment can cover the manufacturing, distribution, sales, consumption, and waste disposal phases, emphasizing the need for efficiency throughout the life cycle of textile and clothing products. In addition, it is possible to extend efficiency analysis to production methods using renewable energies and ecological processes for the sustainable manufacture of textiles.

## CONCLUSION

The aim of this study is to analyze the financial efficiency of the textile and clothing industry in Portugal, examining the performance from 2003 to 2022 and the correlation between spending on research and development (R&D) and return on assets.

The results reveal a notable disparity in financial efficiency between industry subsectors (14.36% to 74.81%), emphasizing the need for innovative strategies. In Portugal's textile and clothing sectors, innovation, research, and modernization are essential for increasing efficiency. The results show that there is a positive correlation between levels of investment in R&D and increased productivity.

The study highlights the challenges the Portuguese textile sector faces, including low financial efficiency and obsolete assets. However, it identifies opportunities through the adoption of innovative production methods. Understanding the impact of financial efficiency on the circular economy is vital for sustainability. Increasing efficiency throughout the life cycles of textile products is crucial for sustainable practices. The conclusions serve as a basis for formulating policies to promote innovation in the sector.

The study reached several conclusions. The financial efficiency of the textile and clothing industry sectors varies, and the data point to different levels of financial efficiency. The industry subsectors have zero, moderate, and high levels of financial efficiency, and it is possible to define benchmarking periods. The clothing industry sector has higher levels of financial inefficiency compared to the textile sector. A low ratio of R&D expenditure to return on assets is observed in all sectors. The textile industry tends to be more technically efficient than the clothing industry. Finally, a more efficiency-centered view of the clothing industry subsectors is needed to achieve gains in the ratio of R&D expenditure to return on assets.

The study has some limitations, including its reliance on historical data, which potentially does not fully represent the current situation in the sector. The efficiency assessment was carried out based on specific indicators, and the use of alternative metrics could provide more information. In addition, the study only analyzes financial efficiency, neglecting crucial aspects such as operational efficiency and product quality.

Despite its limitations, the study provides a broad overview of the financial efficiency levels of the textile and clothing industry in Portugal, highlighting the need to improve the industry's performance.


http://dx.doi.org/10.21511/ppm.22(1).2024.55

## AUTHOR CONTRIBUTIONS

Conceptualization: Ricardo de Moraes e Soares.
Formal analysis: Ricardo de Moraes e Soares.
Investigation: Ricardo de Moraes e Soares.
Methodology: Ricardo de Moraes e Soares, Alexandre Morais Nunes.
Project administration: Ricardo de Moraes e Soares.
Resources: Ricardo de Moraes e Soares, Alexandre Morais Nunes, Paula Heliodoro, Vanda Martins.
Software: Ricardo de Moraes e Soares.
Supervision: Ricardo de Moraes e Soares.
Visualization: Ricardo de Moraes e Soares, Alexandre Morais Nunes, Paula Heliodoro, Vanda Martins.
Writing – original draft: Ricardo de Moraes e Soares.
Writing – review & editing: Ricardo de Moraes e Soares, Alexandre Morais Nunes, Paula Heliodoro, Vanda Martins.

## ACKNOWLEDGMENT

This article is financed by Instituto Politécnico de Setúbal [Polytechnic Institute of Setúbal].

## REFERENCES

1. Ar, I. M., & Baki, B. (2007). Measuring and evaluating efficiency of a glass company through data envelopment analysis. *Problems and Perspectives in Management, 5*(1), 72-81. Retrieved from https://www.businessperspectives.org/images/pdf/applications/publishing/templates/article/assets/567/PPM_EN_2007_01_Ar.pdf
2. Associação Têxtil e Vestuário de Portugal (ATP). (2019). *A fileira têxtil e vestuário no horizonte 2025 [The textile and clothing industry in 2025].* Associação Têxtil e Vestuário de Portugal. (In Portuguese). Retrieved from https://atp.pt/wp-content/uploads/2020/04/A-fileira-t%C3%AAxtil-e-vestu%C3%A1rio-no-horizonte-2025-1.pdf
3. Barbosa, F. C., & Fuchigami, H. Y. (2018). *Análise envoltória de dados: teoria e aplicações práticas [Data envelopment analysis: Theory and practical applications].* ULBRA. (In Portuguese). Retrieved from https://conhecimentolivre.org/wp-content/uploads/2019/03/Livro-DEA1.pdf
4. Basto, R., Martins, A., & Nogueira, G. (2021). *The impact of R&D tax incentives in P*ortugal (GEE Paper 158). Office for Strategy and Studies of the Ministry of Economy and Digital Transition. Retrieved from https://www.gee.gov.pt/RePEc/WorkingPapers/GEE_PAPERS_158.pdf
5. Cardoso, R. M. N., & Ferreira, V. H. S. (2013). *A relação entre a gestão da qualidade a inovação e a performance no setor do têxtil em Portugal [The relationship between quality management, innovation and performance in the Portuguese textile sector]* (Master's Thesis). Leiria: Polytechnic Institute of Leiria. (In Portuguese). Retrieved from http://hdl.handle.net/10400.8/1104
6. Confederação Empresarial de Portugal (CIP). (2017). *O conceito de reindustrialização, indústria 4.0 e política industrial para o século XXI: O caso português [The concept of reindustrialisation, industry 4.0 and industrial policy for the 21st century: The Portuguese case].* Confederação Empresarial de Portugal. (In Portuguese). Retrieved from https://cip.org.pt/wp-content/uploads/2017/12/Conselho_Industria_Portuguesa_final-LR.pdf
7. Costa, B. J. F. (2022). *Circular economy in the Portuguese hotel industry.* Seville: University of Seville. Retrieved from https://hdl.handle.net/11441/146165
8. Darji, I., & Dahiya, S. (2023). Measuring operational efficiency of the textile industry using DEA technique: A study of the northern state of India. *Measuring Business Excellence, 27*(3), 421-432. https://doi.org/10.1108/MBE-10-2022-0124
9. Du, X., Wan, B., Long, W., & Xue, H. (2022). Evaluation of manufacturing innovation performance in Wuhan city circle based on DEA-BCC model and DEA-Malmquist index method. *Discrete Dynamics in Nature and Society, 2022.* https://doi.org/10.1155/2022/2989706
10. Elisa, G. (2023). *Multinational firms and their ability to support sustainability along their global value chains.* Padova: Università degli Studi di Padova. Retrieved from https://hdl.handle.net/20.500.12608/59459
11. European Commission. (2003). *O futuro do sector dos têxteis e do vestuário na União Europeia alargada [The future of the textiles and clothing sector in the enlarged European Union].* (In Portuguese). Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2003:0649:FIN:PT:PDF

12. Ferreira, L. (2018, February 25). *Já há 58 locais em Portugal onde pode pagar com bitcoin [There are already 58 places in Portugal where you can pay with bitcoin]*. (In Portuguese). Retrieved from https://jornaleconomico.pt/noticias/ja-ha-58-locais-em-portugal-onde-pode-pagar-com-bitcoin-273219/

13. Fahmy-Abdullah, M., Sieng, L., & Isa, I. (2018). Technical efficiency in Malaysian textile manufacturing industry: A stochastic frontier analysis (SFA) approach. *International Journal of Economics and Management, 12*(2), 407-419. Retrieved from http://www.ijem.upm.edu.my/vol12no2/4)%20Technical%20Efficiency.pdf

14. Fang, K., Hong, X., Li, S., Song, M., & Zhang, J. (2013). Choosing competitive industries in manufacturing of China under low-carbon economy: A three-stage DEA analysis. *International Journal of Climate Change Strategies and Management, 5*(4), 431-444. https://doi.org/10.1108/IJCCSM-09-2012-0054

15. Fortuna, C. (1993). *O fio da meada: A algodão de Moçambique, Portugal e a economia mundo, 1860–1960 [The thread: Mozambique cotton, Portugal and the world economy, 1860–1960]*. Edições Afrontamento. (In Portuguese). Retrieved from https://www.ces.uc.pt/iframe/publicacoes/csis/03.php

16. Gonçalves, F., & Caraça, J. (1986). A indústria transformadora nacional na encruzilhada: Potencial inovador e competitividade [The national manufacturing industry at the crossroads: Innovative potential and competitiveness]. *Análise Social, 22*(90), 93-108. (In Portuguese). Retrieved from https://www.jstor.org/stable/41010514

17. Jajri, I., & Ismail, R. (2006). *Technical efficiency, technological change and total factor productivity growth in the Malaysian manufacturing sector* (MPRA Paper No. 1956). Munich Personal RePEc Archive. Retrieved from https://mpra.ub.uni-muenchen.de/1956/1/MPRA_paper_1956.pdf

18. Khalil, S. (2011). Relative efficiency of decision-making units producing both desirable and undesirable outputs: A case of textile processing units in Pakistan. *Pakistan Development Review, 50*(4), 685-698. Retrieved from https://www.jstor.org/stable/23617728

19. Li, S., & Tsai, S. (2018). Efficiency of apparel retail at the firm level: an evaluation using data envelopment analysis (DEA). *Journal of Textile Engineering & Fashion Technology, 4*(2), 131-138. https://doi.org/10.15406/jteft.2018.04.00130

20. Liu, C., & Xia, G. (2018). Research on the dynamic interrelationship among R&D investment, technological innovation, and economic growth in China. *Sustainability, 10*(11), Article 4260. https://doi.org/10.3390/su10114260

21. Marques, A. (2023). *Comércio internacional e crescimento a longo prazo: O contexto mundial, notas sobre Portugal [International trade and long-term growth: The global context, notes on Portugal]*. Almedina. (In Portuguese). Retrieved from https://www.almedina.net/comercio-internacional-e-crescimento-a-longo-prazo-o-contexto-mundial-notas-sobre-portugal-1675161933.html

22. Mello, J., Meza, L., Gomes, E., & Neto, L. (2005). Curso de análise de envoltória de dados [Data envelopment analysis course]. *Pesquisa Operacional e o Desenvolvimento Sustentável.* (In Portuguese). Retrieved from http://ws2.din.uem.br/~ademir/sbpo/sbpo2005/pdf/arq0289.pdf

23. Merle, K., & Fermam, R. (2023). Competências para inovar na indústria 4.0 do setor têxtil e de vestuário brasileiro: Uma revisão sistemática da literatura [Competences for innovation in Industry 4.0 in the Brazilian textile and clothing sector: A systematic literature review]. *Revista S&G, 18*(1), 105-111. (In Portuguese). https://doi.org/10.20985/1980-5160.2023.v18n1.1773

24. Montagna, C., & Carvalho, G. (2018). *Textiles, identity and innovation: Design the future* (1st ed.). CRC Press. https://doi.org/10.1201/9781315100210

25. Montenegro, R. L. G. (2011). Padrões concorrenciais têxtil-confecção sob o enfoque da aglomeração local de Nova Friburgo [Textile-confection competition patterns from the perspective of the local agglomeration of Nova Friburgo]. *Acta Scientiarum, Human and Social Sciences, 33*(1), 33-43. (In Portuguese). https://doi.org/10.4025/actascihumansoc.v33i1.8376.

26. Nagy, A. (1999). Portugal's European integration and its effects on her foreign trade. *Acta Oeconomica, 50*(1/2), 191-222. Retrieved from https://www.jstor.org/stable/45046521

27. Nassif, A. (2023). *Desenvolvimento e estagnação: O debate entre desenvolvimentistas e liberais neoclássicos [Development and stagnation: The debate between developmentalists and neoclassical liberals]* (1st ed.). Editora Contracorrente. (In Portuguese). Retrieved from https://www.editoracontracorrente.com.br/product/desenvolvimento-e-estagnacao-o-debate-entre-desenvolvimentistas-e-liberais-neoclassicos

28. Neto, A. M. (1991). *Industrialização de Angola: Reflexão sobre a experiência da administração portuguesa, 1961–1975 [Industrialization in Angola: A reflection on the experience of the portuguese administration, 1961–1975]*. Escher. (In Portuguese). Retrieved from https://biblioteca.cm-moita.pt/SearchResultDetail.aspx?mfn=13535&DDB=

29. Nikam, J. (2003). *Gaps, challenges and drivers for environmentally sustainable textile and garment manufacturing in India* (SEI Working Paper). Stockholm Environment Institute. https://doi.org/10.51414/sei2023.033

30. Nogueira, P. M. R. (2020). *A ciência e a tecnologia na indústria têxtil e do vestuário: Uma abordagem historiográfica ao setor em Guimarães [Science and technology in the textile and clothing industry: A historiographical approach to the sector in Guimarães]* (Master's



http://dx.doi.org/10.21511/ppm.22(1).2024.55

Thesis). Coimbra: University of Coimbra. (In Portuguese). Retrieved from https://hdl.handle.net/10316/95071

31. Pereira, B. M. R. (2021). *Análise dos determinantes da produtividade na indústria têxtil e de vestuário Portuguesa [Analysing the determinants of productivity in the Portuguese textile and clothing industry]* (Master's Thesis). Braga: University of Minho. (In Portuguese). Retrieved from https://hdl.handle.net/1822/76100

32. Pérez, K., González-Araya, M., & Iriarte, A. (2017). Energy and GHG emission efficiency in the Chilean manufacturing industry: Sectoral and regional analysis by DEA and Malmquist indexes. *Energy Economics, 66*, 290-302. https://doi.org/10.1016/j.eneco.2017.05.022

33. Popker, S. M., & Raju, G. A. (2020). Financial performance and efficiency of cotton textile companies – An DEA approach. *Journal of Advanced Research in Dynamical and Control Systems, 12*(4), 1753-1761. https://doi.org/10.5373/JARDCS/V12SP4/20201658

34. Proença, A., Amaro, L., & Fragoso, R. (2008). Sector têxtil e vestuário [Textile and clothing sector]. In J. Leitão, J. Ferreira, & S. Azevedo (Eds.), *Dimensões competitivas de Portugal: Contributos dos territórios, sectores, empresas e logística [Portugal's competitive dimensions: Contributions from territories, sectors, companies and logistics]*. Centro Atlântico. (In Portuguese). Retrieved from https://www.wook.pt/livro/dimensoes-competitivas-de-portugal-joao-leitao/203706

35. Proença, C. (2018). *Estudo de caso aplicado a empresa do sector têxtil e do vestuário [Case study applied to a company in the textile and clothing sector]* (Master's Thesis). Covilhã: University of Beira Interior. (In Portuguese). Retrieved from http://hdl.handle.net/10400.6/9457

36. Puime-Guillén, F., Enríquez-Díaz, J., & Castro-Santos, L. (2021). *Financial management and risk analysis strategies for business sustainability.* IGI Global. Retrieved from https://www.igi-global.com/book/financial-management-risk-analysis-strategies/264887

37. Rai, A. (2013). Measurement of efficiency in the airline industry using data envelopment analysis. *Investment Management and Financial Innovations, 10*(1), 38-45. Retrieved from https://www.businessperspectives.org/images/pdf/applications/publishing/templates/article/assets/5005/imfi_en_2013_01_Rai.pdf

38. Rakhmawan, C., Hartono, D., & Awirya, A. (2012). Efficiency and import penetration on the productivity of textile industry and textile products. *International Research Journal of Business Studies, 5*(3), 51-63. https://doi.org/10.21632/irjbs.5.3.51-63

39. Sangeetha, R. (2020). How efficient are public sector banks in India? A nonparametric approach. *Banks and Bank Systems, 15*(4), 108-120. http://dx.doi.org/10.21511/bbs.15(4).2020.10

40. Santos, D. (2011). *Dinâmicas territoriais de inovação [Territorial dynamics of innovation]*. Edições Húmus. (In Portuguese). Retrieved from https://edicoeshumus.pt//index.php?route=product/product&product_id=592&search=Din%C3%A2micas+territoriais+de+inova%C3%A7%C3%A3o&description=true

41. Shewell, P., & Migiro, S. (2016). Data envelopment analysis in performance measurement: A critical analysis of the literature. *Problems and Perspectives in Management, 14*(3-3), 705-713. http://dx.doi.org/10.21511/ppm.14(3-3).2016.14

42. Silva, P. M. (2013). *As redes de relacionamento e as capacidades dinâmicas: A indústria têxtil e de vestuário Portuguesa [Relationship networks and dynamic capabilities: The Portuguese textile and clothing industry]* (Master's Thesis). Braga: University of Minho. (In Portuguese). Retrieved from https://hdl.handle.net/1822/24951

43. Soares, R. de M., & Pinheiro, P. (2023). Fiscal attractiveness of Portuguese municipalities. *Public and Municipal Finance, 12*(2), 1-16. http://dx.doi.org/10.21511/pmf.12(2).2023.01

44. Sousa, A. G. H. (2020). *A inovação na indústria têxtil e vestuário: O papel da colaboração [Innovation in the textile and clothing industry: The role of collaboration]* (Master's Thesis). Lisbon: University of Lisbon. (In Portuguese). Retrieved from http://hdl.handle.net/10400.5/20912

45. Sudri, N., Theresia, L., Widianty, Y., Puspiptek, J., Selatan, K., & Banten, P. (2019). Increasing textile industry production process efficiency with data development analysis. *Iptek, 3*(2019), 239-244. Retrieved from https://jurnaliptek.iti.ac.id/index.php/jii/article/view/154/60

46. Sueyoshi, T., & Goto, M. (2019). DEA non-radial approach for resource allocation and energy usage to enhance corporate sustainability in Japanese manufacturing industries. *Energies, 12*(9), Article 1785. https://doi.org/10.3390/en12091785

47. World Intellectual Property Organization (WIPO). (2005). *Um ponto no tempo: O uso inteligente da propriedade intelectual por empresas do setor têxtil [A stitch in time: The intelligent use of intellectual property by companies in the textile sector]*. WIPO. (In Portuguese). Retrieved from https://tind.wipo.int/record/40447/files/wipo_pub_794.pdf

48. Zenzerovic, R., Rabar, D., & Cerne, K. (2023). A longitudinal analysis of economic activities' relative efficiency using the DEA approach. *Economies, 11*(11), Article 281. https://doi.org/10.3390/economies11110281