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LEAN MANUFACTURING AND RETURN ON EQUITY: EVIDENCE FROM SLOVENIAN MANUFACTURING FIRMS USING THE DUPONT MODEL

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A B S T R A C T

Lean manufacturing is widely recognized as an operational philosophy of process improvement; however, its relationship with financial performance remains relatively underexplored empirically. The purpose of this study is to examine the relationship between lean manufacturing and return on equity (ROE), and to link operational improvements with financial outcomes through the DuPont model. The research comprises a comparative financial analysis of a selected manufacturing company for the period 2019–2023, as well as a quantitative analysis of a sample of 240 Slovenian manufacturing enterprises. Descriptive statistical methods, correlation analysis, and linear regression with a composite lean maturity index were employed. The results indicate that ROE in the analyzed company increased from 4.74% to 11.99%, with growth primarily driven by improvements in net profit margin and process efficiency rather than by increased financial leverage. The empirical analysis demonstrates a statistically significant positive association between the level of lean maturity and ROE ($\beta = 0.255$; $R^2 = 0.065$; $p < 0.001$; $N = 240$). Although the explained variance is moderate, the findings indicate that lean maturity represents a statistically significant and managerially relevant determinant of financial performance within a multifactor business environment. The contribution of the study lies in the integration of the Lean approach with the DuPont model as an analytical bridge between production and financial functions, as well as in the empirical validation of this relationship within the Slovenian industrial context.

1. INTRODUCTION

Lean manufacturing is widely recognized in the literature as an operational philosophy of process improvement (Womack, 2003, Ohno, 1988) however, its strategic value becomes evident only through the analysis of aggregated financial performance indicators (Shah & Ward, 2003). While the effects of Lean on quality, lead times, and inventory levels have been empirically confirmed (Fullerton et al., 2014; Shah & Ward, 2007) the question of how and through which financial mechanisms Lean influences return on equity (ROE) remains subject to ongoing debate (Fullerton et al., 2013). Understanding this relationship requires moving beyond a purely operational perspective and applying analytical frameworks that enable the decomposition of financial performance into its structural components, as provided by the DuPont approach (Higgins, 1977).

Lean manufacturing has evolved into a comprehensive organizational paradigm that extends beyond the application of individual tools and techniques. Rooted in the Toyota Production System (Ohno, 1988) and the principles of the Toyota Way (Liker, 2004), it emphasizes waste elimination, process stability, standardization, respect for employees, and long-term orientation. Lean is systematized through 14 principles

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that integrate operational, organizational, and cultural dimensions of firm performance (Liker, 2004; Shah & Ward, 2003).

Numerous empirical studies confirm that lean practices positively affect operational performance, including reductions in lead times, inventory levels, improvements in quality, and increased productivity (Fullerton et al., 2014; Shah & Ward, 2007). Nevertheless, the impact of Lean on financial performance, particularly on return on equity (ROE), remains less clearly defined. Financial indicators are aggregated measures influenced by multiple factors, and the effects of operational improvements are often reflected with a time lag (Fullerton et al., 2013).

2. LITERATURE REVIEW

A systematic review of the literature indicates that most research focuses primarily on the operational outcomes of Lean, whereas findings regarding financial effects remain inconsistent (Neely, 2005). Scholars highlight methodological differences, inadequate operationalization of lean constructs, and limited understanding of the linkage between operational and financial metrics. Moreover, recent studies suggest that traditional accounting systems frequently fail to capture the financial effects of Lean in a timely manner, potentially leading to an underestimation of its financial contribution (Bhasin, 2012; Garza-Reyes, 2015).

To better understand the financial implications of Lean, the application of DuPont analysis is particularly appropriate, as it decomposes return on equity into net profit margin, asset turnover, and financial leverage. Such an approach enables the identification of the mechanisms through which operational improvements translate into financial performance outcomes (Figure 1).

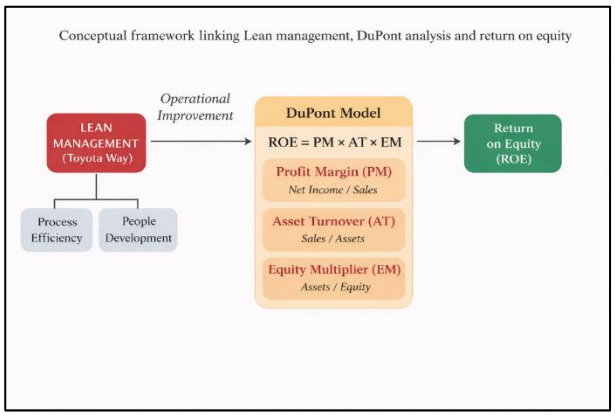

Figure 1. Conceptual framework linking Lean manufacturing, DuPont analysis, and return on equity (ROE)

A systematic review of the literature identifies several key research gaps:

- Most studies do not decompose ROE into its individual components and therefore fail to explain the specific financial mechanisms through which Lean influences return on equity.
- There is a lack of longitudinal (panel) case studies comparing periods before and after Lean implementation in real industrial environments.
- Research rarely links specific lean principles and practices, or their complementary bundles (lean bundles), to distinct financial outcomes (Furlan et al. 2011).
- Empirical studies focusing on medium-sized manufacturing enterprises within the Slovenian context remain scarce.

This study aims to examine the impact of Lean manufacturing implementation on return on equity (ROE) in a medium-sized manufacturing enterprise by applying DuPont analysis and identifying the key financial mechanisms through which Lean influences financial performance.

The model presents the conceptual framework of the study. Lean principles influence financial performance indirectly through operational improvements that are reflected in the components of the DuPont model. Enhancements in process efficiency and people development contribute to higher net profit margins and improved asset turnover, while process stabilization reduces the need for increased financial leverage. In this way, Lean manufacturing affects ROE through structured financial mechanisms rather than merely through isolated operational improvements.

In recent years, research on lean practices has increasingly shifted from operational outcomes toward financial implications, emphasizing the linkage between Lean and disaggregated financial indicators, such as those provided by DuPont analysis. Empirical studies have demonstrated a positive impact of lean practices on key financial metrics, including return on equity, net profit margin, and return on assets (Abreu-Ledón et al., 2018; Dieste et al., 2021), highlighting the need for integrated frameworks that connect operational and financial performance.

Furthermore, the role of digitalization and Industry 4.0 practices in strengthening the effect of lean approaches on operational efficiency and financial outcomes (including ROE) has been increasingly emphasized (Buer et al., 2018; Rossini et al., 2019; Rossini et al., 2022). Meta-analyses and systematic reviews confirm that lean practices have a statistically significant positive effect on financial performance, while also cautioning against conflating correlation with causation (Antony et al., 2021; Sharma et al., 2021).

Some studies additionally underline how the integration of lean practices with sustainability strategies and digital technologies influences firms' long-term financial performance (Bhamu & Sangwan, 2014; Furlan et al., 2011; Leng et al., 2024; Rossini et al., 2022).

3. METHODOLOGY

3.1 DuPont analysis

The study employed a quantitative case study design with a comparative analysis of two time points (2019 and

2023). The units of analysis were the company's financial indicators, namely return on equity (ROE), net profit margin (NPM), asset turnover (AT), and equity multiplier (EM). The following research instruments were employed: (1) secondary data analysis of audited annual reports, (2) a Lean diagnostic matrix consisting of 28 criteria evaluated on a five-point Likert scale, and (3) process performance datasets extracted from the company's information system.

Statistical data processing included descriptive statistics, calculation of relative changes, DuPont decomposition, Pearson correlation analysis, and linear regression to assess the effect of lean maturity level on ROE. The reliability of the Lean diagnostic matrix (28 criteria) was verified using Cronbach's alpha coefficient ($\alpha = 0.87$). The reliability of the individual constructs of the Toyota Way model (philosophy, process, people & partners, problem-solving) was additionally assessed and is presented in Table 4.

The case study is based on the annual reports of the selected company for the years 2019 and 2023. The analytical framework integrates financial techniques, Lean diagnostic tools, and organizational comparative analysis. The methodological design is supported by both classical financial literature and contemporary Lean research (Ohno, 1988; Shah & Ward, 2003; Shah, & Ward, 2007). DuPont analysis originates from the DuPont Corporation, where it was developed in the early twentieth century as a systematic method for evaluating return on equity (Higgins, 1977). Its key innovation lies in decomposing ROE into three core components, thereby enabling management to identify the structural drivers of financial performance.

The fundamental DuPont identity is expressed as: ROE = NPM × AT × EM, where NPM is calculated in decimal form and the resulting ROE is subsequently expressed as a percentage:

- NPM – Net Profit Margin represents the proportion of net income generated per unit of revenue.
- AT – Asset Turnover captures the efficiency with which total assets are utilized to generate revenue.
- EM – Equity Multiplier reflects the firm's degree of financial leverage, defined as the ratio of total assets to equity. The theoretical relationship between capital structure and profitability is traditionally grounded in the Modigliani–Miller proposition (Dang et al., 2014).

The DuPont model represents not only a mathematical identity but also an analytical framework that facilitates the examination of the interdependencies among operational, investment, and financing decisions within the firm (Higgins, 1977).

Lean implementation affects all three DuPont components:

- NPM improves through the reduction of waste, defects, and customer complaints, alongside gains in productivity (Shah & Ward, 2003).
- AT increases as a consequence of improved flow, lower inventory holdings, and enhanced asset utilization (Rother & Shook, 1999).
- EM may decline, as stable Lean processes reduce reliance on external financing, leading to greater capital efficiency (Fullerton et al., 2013).

The financial effects of lean methods are not immediately observable; rather, they become evident only after the organizational culture has been stabilized and standardized, which represents a key methodological assumption of this study (Fullerton et al., 2014).

The DuPont method was applied because it:

- enables comparison before and after the implementation of Lean manufacturing,
- identifies which component contributes most significantly to ROE growth,
- facilitates the linkage between process improvements and financial outcomes,
- ensures methodological alignment with established research practices in the Lean literature (Bhasin, 2012).

The application of the DuPont model in the context of Lean transformations is appropriate, as Lean interventions affect costs, productivity, lead times, and asset utilization—variables that are financially reflected in the components of the DuPont model.

Process indicators were analyzed in accordance with value stream mapping (VSM) methodology (Rother & Shook, 1999). In this study, the following process parameters were examined:

- Inventory levels (affecting asset turnover and lead times),
- Capital investments in equipment (influencing process stability and overall equipment effectiveness – OEE),
- Productivity (affecting net profit margin and capacity utilization).

Process analysis reveals "hidden" losses that are not captured by accounting statements but are systematically identified through lean methodology (Hines et al., 2004).

Organizational changes before and after the implementation of Lean manufacturing were assessed with regard to:

- the level of standardization,
- process stability,
- the presence of visual management practices,
- the maturity of a continuous improvement culture (Kaizen approach) (Imai, 1986).

Lean transformation requires both technical changes (processes, flow, tools) and social changes (culture, competencies, leadership), with both dimensions incorporated into the methodological comparison (Shah & Ward, 2003).

The Lean diagnostic matrix was designed based on:

- the seven types of waste (Ohno, 1988),
- the principles of stable flow (Shah & Ward, 2007),
- a maturity assessment framework for Lean systems (Hines et al. 2004).

The matrix enables a qualitative assessment of:

- the level of waste prior to Lean implementation,
- improvements following Lean implementation,
- the degree of alignment between actual processes and Lean principles.

3.2 Empirical testing of hypotheses H1–H4 on a sample of 240 companies in the Republic of Slovenia

The hypotheses were formulated in a manner that enables not only the testing of the statistical significance of the relationships between individual Lean principles and return on equity, but also the assessment of the magnitude of the effect of each principle on corporate financial performance. It is evident that return on equity is influenced by all Lean principles collectively; however, their individual contributions may differ in strength.

Based on the central research question—to what extent do Lean principles influence financial return on equity? - and the underlying theoretical foundations, the hypotheses were developed according to a model examining the impact of the fourteen Lean principles on corporate return on equity (Table 1).

Table 1. Hypotheses formulated based on the central research question

Hypothesis	Statement of Hypotheses
Hypothesis H1:	There is a statistically significant positive relationship between the group of principles within the <PHILOSOPHY> category and return on equity.
Hypothesis H2:	There is a statistically significant positive relationship between the group of principles within the <PROCESS> category and return on equity.
Hypothesis H3:	There is a statistically significant positive relationship between the group of principles within the <PEOPLE AND PARTNERS> category and return on equity.
Hypothesis H4:	There is a statistically significant positive relationship between the group of principles within the <PROBLEM-SOLVING> category and return on equity.
Hypothesis H5	There is a statistically significant positive relationship between the overall level of Lean implementation (composite Toyota Way index) and return on equity (ROE).

Statistical data processing included Pearson correlation (r), Spearman correlation (ρ), and construct reliability assessment using Cronbach's alpha (α). The statistical analysis presents the results of testing hypotheses H1–H4 on a sample of 240 companies.

The companies were selected from the AJPES database and included enterprises classified under Section C (Manufacturing) according to the Standard Classification of Activities (NACE Rev. 2 / SKD 2008), with available financial data for the period 2018–2022. This sample definition ensures a focus on manufacturing firms and enhances the comparability of financial indicators. The analysis enabled empirical verification of the formulated research hypotheses.

The position of the selected Company A was evaluated relative to the other firms in the sample. For this purpose, a standardized z-score was calculated to express the deviation of Company A from the sample mean in units of standard deviation, and percentile ranking was used to indicate the proportion of companies achieving lower values than Company A. This approach provides a clear assessment of the relative competitive position of Company A within the sample.

4. RESULTS

4.1 Descriptive statistics

Descriptive analysis indicates a relatively high level of Lean implementation within the analyzed sample (N = 240). The composite ToyotaWay_Total index achieves an average value above the midpoint of the scale. The average return on equity (ROE AVG) for the period 2018–2022 exhibits moderate variability across companies.

4.2 DuPont analysis of Company A

The DuPont decomposition for Company A over the period 2019–2023 indicates an increase in ROE from 4.74% to 11.99%. The growth was primarily driven by improvements in net profit margin, while asset turnover increased moderately. The equity multiplier declined, suggesting that the rise in ROE was not driven by increased financial leverage but rather by enhanced operational efficiency.

DuPont analysis of ROE (2019 vs. 2023)(Table 2):

Financial data extracted from audited annual reports:

2019:

- NPM = 190.284 / 8.685.303 = 2.19 %,
- AT = 8.685.303 / 6.581.279 = 1.32,
- EM = 6.581.279 / 4.001.248 = 1.64,
- ROE 2019 = 2.19 % × 1.32 × 1.64 = 4.74 %.

2023:

- NPM = 788.462 / 11.842.348 = 6.66 %,
- AT = 11.842.348 / 8.682.081 = 1.36,
- EM = 8.682.081 / 6.518.608 = 1.33,
- ROE 2023 = 6.66 % × 1.36 × 1.33 = 11.99 %.

Table 2. Changes in DuPont model components

Component	2019	2023	Change
NPM	2.19 %	6.66 %	+204 %
AT	1.32	1.36	+3 %
EM	1.64	1.33	-19 %
ROE	4.74 %	11.99 %	+153 %

Interpretation:

- The largest contribution to ROE growth stems from the increase in NPM, consistent with the implemented Lean initiatives, the reduction in customer complaints, and higher productivity.
- AT improved slightly, indicating stable efficiency in asset utilization.
- EM decreased, suggesting lower debt levels and reduced financial leverage, resulting in a more financially stable capital structure.
- ROE more than doubled, which is consistent with the improvement in operational efficiency following Lean implementation.

The results can be interpreted on several interrelated levels. The first level is operational-process oriented, where the implementation of Lean methods directly affects the reduction of waste, process stabilization, and more efficient utilization of production resources (Shah & Ward, 2003; Womack, 2003). The more than threefold increase in net profit margin during the analyzed period indicates that the improvement was not merely a consequence of revenue growth, but primarily of enhanced internal efficiency. Standardization of procedures, reduction of customer complaints, and systematic problem-solving contributed to lowering the

costs of poor quality, which was directly reflected in the NPM indicator. The literature emphasizes that the financial effects of Lean practices often materialize through improvements in process efficiency, inventory management, and inventory leanness (Fullerton et al., 2014; Hofer et al., 2012; Koumanakos, 2008), while the combination of Lean approaches and digital solutions further strengthens organizational performance (Tortorella & Fettermann, 2018).

The second level is financial-structural. The DuPont decomposition reveals that ROE growth was predominantly driven by operational factors, whereas the equity multiplier declined. This suggests that the increase in profitability was not based on higher financial leverage, but rather on improved business efficiency. Such a pattern is consistent with studies highlighting that Lean organizations tend to reduce capital tied up in inventory over the long term and enhance capital efficiency (Banker et al., 2008; Koumanakos, 2008; Netland & Ferdows, 2016).

The third level relates to organizational culture and managerial mechanisms. Progress in visual management, team-based problem-solving, and employee involvement indicates a higher level of Lean maturity, which acts as a mediator between tool implementation and financial outcomes (Netland & Ferdows, 2016; Shah & Ward, 2007). The regression results confirm a statistically significant positive relationship between comprehensive Lean implementation and ROE ($\beta = 0.255$; $p < 0.001$), supporting the systemic nature of the effect.

An important dimension is also the digitalization of production. The implementation of a digital twin and quality monitoring applications enabled improved data capture and faster decision-making, supporting findings that the integration of Lean principles with digital technologies and advanced industrial AI solutions generates synergistic effects on organizational performance (Leng et al., 2024; Tortorella & Fettermann, 2018).

The results suggest that Lean manufacturing extends beyond project-based optimization and represents a strategic transformation of the business model. The increase in value added per employee by more than 50%, together with the stable improvement of the DuPont components, indicates a sustained shift toward greater process and financial efficiency.

Despite these positive findings, certain limitations must be acknowledged. The analysis is based on a single organization, which limits generalizability. Financial indicators may also be influenced by external factors such as market conditions or changes in cost structures. However, the temporal alignment between Lean implementation and performance improvement, together with consistency with prior literature, supports the interpretation that Lean can represent a significant determinant of financial performance.

From a practical perspective, this implies that Lean effects should be measured holistically, incorporating the DuPont model as an analytical bridge between operational indicators and financial outcomes. Future research should include broader samples of companies and longer time series (see literature overview in Table 3).

Table 3. Comparative overview of findings and relevant literature

Area	Our Findings	Literature
NPM and ROE	The primary driver of ROE growth is NPM	Shah & Ward [4]; Fullerton et al. [6]
Asset turnover	Moderate increase in AT	Koumanakos [16]
Financial leverage	Decrease in EM	Banker et al. [18]
Digitalization	Synergy between Lean and digital tools	Tortorella & Fettermann [14]

4.3 Correlation analysis

Pearson correlation analysis indicates statistically significant positive relationships between all four Toyota Way dimensions and ROE_AVG ($p < 0.01$). The correlation coefficients range from $r = 0.17$ to $r = 0.29$. In addition to Pearson's coefficient, Spearman's rank correlation coefficient was calculated to confirm the robustness of the results irrespective of the normality assumption. The comparison of both measures demonstrates that the findings are methodologically stable and not sensitive to potential deviations from normal data distribution.

It should be noted that the PROCESS and PEOPLE & PARTNERS dimensions exhibit nearly identical Pearson correlation coefficients. The difference appears only at the fourth decimal place and, due to rounding to three decimal places, is presented as the same value. This does not indicate a methodological inconsistency but rather reflects a similar linear association of both constructs with ROE.

4.4 Hypothesis testing

The analysis presents the results of testing hypotheses H1–H4 (Table 5) on a sample of 240 companies. The independent variables consist of composite Toyota Way constructs, while the dependent variable is the average return on equity (ROE) for the period 2018–2022.

The selected company is treated in the article as anonymized Company A and is displayed in comparison with other firms in a representative graph (Figure 2), marked with the label X. The reliability of the constructs is reported in Table 4 below.

Table 4. Construct reliability (Cronbach's α)

Construct	Cronbach α	N (Complete cases)
Philosophy	0.965	240
Process	0.985	240
People & Partners	0.979	240
Problem-Solving	0.981	240

Table 5. Results of the correlation analysis (H1–H4)

Hypothesis	Dimension	N	Pearson r	p-value	Spearman ρ	p-value
H1	Philosophy	240	0.166 **	0.010	0.198 **	0.002
H2	Process	240	0.290 ***	<0.001	0.431 ***	<0.001
H3	People & Partners	240	0.290 ***	<0.001	0.452 ***	<0.001
H4	Problem-Solving	240	0.292 ***	<0.001	0.475 ***	<0.001

Pearson correlation (r) and Spearman correlation (ρ). Significance: * p < 0.05; ** p < 0.01; *** p < 0.001.

Comparison: Selected Company A (anonymous) vs. Other Companies

Selected Company A is identified in the article as anonymized. Below is a comparison relative to the average of the remaining companies (z-score) and its percentile position within the sample (excluding Company A) – Table 6.

Table 6. Comparison between the Selected Company and All Other Companies in the Study

Variable	Company A	Average (Others)	z-score	Percentile Rank
Philosophy	4.778	4.406	0.626	60.3
Process	3.868	4.133	-0.515	20.5
People & Partners	3.960	4.161	-0.382	25.7
Problem-Solving	4.421	4.098	0.519	70.3
ROE_AVG	9.592	15.514	-0.268	40.3

The position of the anonymized selected Company A was assessed in comparison with the other companies in the sample. A z-score was used to express the deviation of Company A from the mean of the remaining companies, measured in units of standard deviation. In addition, the percentile rank indicates the proportion of companies achieving lower values than Company A. This approach provides a clear insight into the relative competitive position of Company A within the sample.

Figure 2 presents a representative example of the relationship between the process dimension of lean principles and ROE. The remaining relationships are reported above in Table 5.

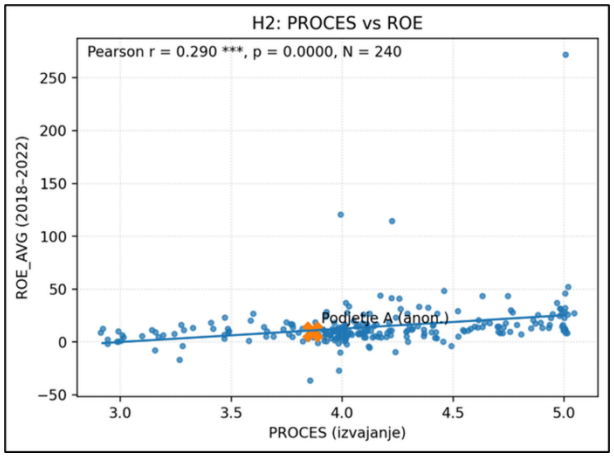

Figure 2. H2: The hypothesis is confirmed (Pearson r = 0.290 ***, Spearman ρ = 0.431 ***, N = 240)

4.5 Linear regression analysis (dependent variable: ROE AVG, N = 240)

In the following section, Hypothesis H5 is tested, which assumes a statistically significant positive relationship between the overall implementation of lean principles (ToyotaWay_Total) and return on equity (ROE).

Table 7. Model Summary

R^2	Adjusted R^2	F (1.238)	p (model)
0.065	0.061	16.58	< 0.001

Table 8. Regression Coefficients

Variable	B	SE B	β (standard.)	t	p
(Constant)	-57.644	17.669	—	-3.262	0.001
TW_TOTAL	15.912	3.908	0.255	4.071	< 0.001

Note: ROE_AVG represents the average return on equity (2018–2022). TOYOTAWAY_TOTAL is the mean composite index of the four dimensions (Philosophy, Process, People and Partners, and Problem Solving).

The results of the linear regression analysis (Table 7 and Table 8) indicate that the overall Toyota Way index statistically significantly predicts return on equity ($F(1, 238) = 16.58$; $p < 0.001$). The model explains 6.5% of the variance in ROE ($R^2 = 0.065$). Although the proportion of explained variance is relatively modest, such a result is expected in the context of financial performance, which is shaped by numerous internal and external factors. In a multifactorial environment, even a moderate effect may represent a managerially relevant contribution.

Cohen's effect size index ($f^2 \approx 0.07$) indicates a small-to-moderate effect, consistent with the multifactorial nature of corporate financial performance.

The assumptions of linear regression were examined through visual inspection of residuals and additional diagnostic tests (VIF, Shapiro–Wilk, and Breusch–Pagan), none of which indicated statistically significant violations.

A graphical representation of the regression line is not included, as the interpretation is based on the regression coefficients, effect size, and statistical significance of the model, which is methodologically appropriate for testing Hypothesis H5.

5. DISCUSSIONS

The results support Hypothesis H5 and indicate a statistically significant association between the comprehensive implementation of lean principles and higher return on equity.

Due to the cross-sectional research design and the application of correlation and regression analyses, the findings should be interpreted as statistically supported associations rather than evidence of causal relationships.

The DuPont analysis further suggests that the improvement in ROE is primarily related to operational efficiency rather than an increase in financial leverage.

The findings are consistent with the existing literature, which emphasizes the indirect impact of lean practices on financial indicators through improvements in process efficiency. Future research should include broader samples of companies and longer time series. The correlation analysis also supports Hypotheses H1–H4, as all four dimensions of leanness demonstrate statistically significant positive associations with ROE

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6. CONCLUSIONS

The aim of the study was to examine the relationship between the implementation of lean manufacturing and return on equity (ROE) in a medium-sized manufacturing enterprise, and to explain the financial mechanisms underlying this relationship using the DuPont decomposition framework. The empirical results indicate that ROE increased from 4.74% to 11.99% over the period 2019–2023, with the primary driver being a substantial rise in net profit margin. A moderate improvement in asset turnover, combined with a simultaneous decrease in the equity multiplier, suggests that the growth in profitability was not driven by increased financial leverage, but rather by enhanced operational efficiency and process stabilization.

The results of the correlation analysis conducted on a sample of 240 companies confirm statistically significant associations between all four dimensions of lean principles (Philosophy, Process, People and Partners, and Problem Solving) and return on equity. These findings support the argument that lean manufacturing represents a systemic approach whose effects extend beyond the operational level and are reflected in the financial performance of the firm.

The main contribution of the study lies in the integration of lean principles with the DuPont model, which enables a clearer understanding of the pathways through which operational improvements influence financial indicators. The DuPont framework proved to be an appropriate analytical bridge between production and financial functions, as it allows for a structured interpretation of the determinants of ROE.

Despite the positive results, several limitations should be acknowledged. The case study is based on a single company, which limits generalizability, and financial indicators may be partially influenced by external factors. Furthermore, the empirical analysis of the 240-company sample is based on a cross-sectional design; therefore, the findings cannot be interpreted as evidence of causal effects but rather as statistically significant associations between constructs. Future research should include a larger number of companies, longer time series, and separate analyses of individual lean tools and moderating factors such as leadership style and level of digitalization.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Financial data were obtained from publicly available company reports and the AJPES database, while survey data were collected anonymously and processed in aggregated form to ensure confidentiality.

Author contributions

Conceptualization: Sandi Povše; Methodology: Sandi Povše; Formal analysis: Sandi Povše; Investigation: Sandi Povše; Data curation: Sandi Povše; Writing – original draft: Sandi Povše; Writing – review & editing: Sandi Povše; Visualization: Sandi Povše; Supervision: Mentor – Mirko Markič.

All authors have read and agreed to the published version of the manuscript

AI-Assisted Writing

Artificial intelligence tools were used solely for language refinement, formatting support and structural optimization of the manuscript. All analytical procedures, data interpretation, statistical analyses and scientific conclusions were performed and verified by the author. The author takes full responsibility for the content of the manuscript.

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