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The relationship between lean manufacturing, environmental damage, and firm performance

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Abstract Prior research has found mixed results of leanness, with a counter idea being that slack allows flexibility to improve firm financial performance. We first seek to confirm empirically that leanness in manufacturing does in fact contribute to both lower environmental damage and to improve firm financial performance. With increased awareness of global environmental issues, we incorporate environmental damage measures from Trucost to assess how they may affect firm performance and are affected by leanness. The measures of leanness are calculated based on publically available financial data from Compustat. Based on a final sample of 406 manufacturing firms representing 3594 firm-year observations from 2002 to 2013, the proposed relationships of leanness to firm outcomes and environmental damaged are investigated. A key finding of this study is that a firm should aim its lean efforts to reducing environmental damage, which in turn has more of an effect on improving financial performance than other lean initiatives.

Keywords Lean manufacturing · Environmental performance · Financial performance · Mediation

JEL Classification M14 · O14 · M10

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1 Introduction

Womack et al. (1991) defined the tenets of lean manufacturing, which dictate that processes should not have any wasted materials, motion, or work. Efforts to apply lean practices to manufacturing have been linked widely to improved firm performance in numerous empirical studies (Chen et al. 2007; Swamidass 2007; Capkun et al. 2009; Eroglu and Hofer 2011). While profit is typically the motivation for reducing waste by adopting lean practices, prior research has found that lean management may also impact a firm's environmental performance (King and Lenox 2001a; Rothenberg et al. 2001). Further studies have linked environmental improvements resulting from lean initiatives with changes in firm performance (Porter and van der Linde 1995; King and Lenox 2001b). While these studies generally promote lean as a positive mechanism that in some circumstances improves environmental performance as well as profitability, they do not address the complexities of the relationship between lean manufacturing, the costs associated with environmental damages and a firm's financial performance explicitly.

A number of prior studies provide valuable insights into the potential of lean to improve a firm's environmental performance; however, they do not present frameworks that can be used readily to predict the financial impacts of lean on environmental damages and firm performance.

For example, Porter and van der Linde (1995) utilize a series of case study interviews to explore the relationship between environmental waste reduction efforts and firm innovation levels whereas King and Lenox (2001a) investigate the linkages between ISO 9000 and ISO 14,000 adoption and firm performance. Though insightful, neither of these studies link lean, environmental performance and financial performance in a clear and quantifiable manner. Therefore, the objective of this study is to address this gap by empirically examining and quantifying the relationships between firm leanness, environmental performance, and financial performance. The most closely related study to our work is that of Yang et al. (2011). Their study did find relationships between lean, environmental performance, and firm financial performance. However, an issue we overcome with this new study is that their data was based on a survey sent to the companies measuring the internal perceptions of companies regarding environmental initiatives, lean, and financial performance. Our study does not rely on perceptions or a survey with limited answer choices.

Rather, our study examines a sample of manufacturing firms to assess if lean practices are associated with improved environmental and financial performance. We determine financial performance and measure leanness using Compustat recorded financial data. Environmental data is calculated by Trucost for these firms. Having secondary data takes out any potential issues of a firm's wishful thinking of its performance in environmental or financial realms, and reduces issues related to the person filling out the survey not knowing the information fully.

Specifically, in this study, we evaluate if lean practices (evidenced by measures of lean manufacturing) reduce the cost impacts of a firms' damage to environment and further, if the level of financial damage influences a firm's financial performance (measured based on reported total assets and net income). Using this model, we then discuss the potential impact of lean on a typical manufacturing firm's environmental and financial performance.

In the next section, we examine the existing literature to frame and present our research hypotheses. We then describe the research methods we employed for this study. Next, we describe our results. The final section discusses the implications of our findings and conclusions.

2 Literature review and research hypotheses

The impact of lean on manufacturing organizations has been investigated widely within the operations management body of literature. Overwhelming, these studies have found that the reductions in waste resultant from lean initiatives lead to improvements in financial performance. Our study builds on these prior efforts in several ways. First, we validate prior findings that leanness improves performance, we first examine the relationship between leanness and firm performance in our sample of firms. However, since lean efforts can target a variety of wastes, some of which are not directly related to environmental performance, we then explore if the level of leanness does in fact relate to differences in the environmental performance experienced by firms (measured using the cost of environmental damages) and then we test if those damages impact firm performance. Finally, we investigate the interdependency between these factors by assessing if environmental damages mediate the potential benefits of leanness on financial performance. Figure 1 graphically demonstrates the hypothesized relationships and the theoretical foundations, which are discussed in the three following sub-sections.

2.1 Lean and firm performance

Numerous firms have adopted lean practices to reduce waste and, ultimately, to improve profits. By reducing waste, manufacturers use their resources more efficiently, which directly increases firm margins, and hence, firm performance. This relationship has been tested and confirmed in numerous empirical studies focused on manufacturing (e.g. Chen et al. 2007; Swamidass 2007; Capkun et al. 2009; Eroglu and Hofer 2011). Based on the substantial body of existing literature supporting a positive rela-

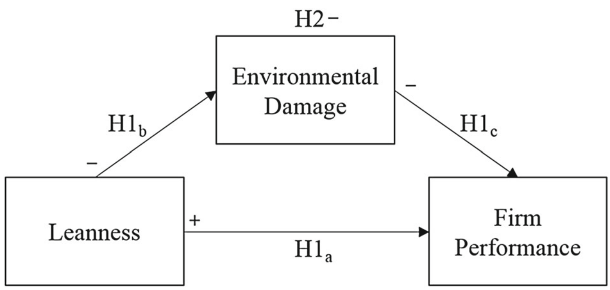

Fig. 1 Hypothesized relationships between leanness, environmental damage, and firm performance

tionship between lean and firm performance, our first hypothesis tests if the expected positive relationship between leanness and firm performance holds true within our sample of firms. Explicitly, we predict:

H1$_a$ More (less) lean firms will have higher (lower) firm financial performance.

2.2 Lean and environmental performance

The extant literature supports a direct link between lean and improved firm financial performance, yet the link between lean production and environmental performance remain less explored. As discussed in Tebini et al. (2015), there is a variety of viewpoints on this matter. Porter and van der Linde (1995) posited that improvements in production quality (a key principle of lean) can occur in concert with efforts to reduce pollution. When these two efforts are aligned, a firm may be compelled to develop an innovative new production method which, in the end, might create a competitive advantage for the firm (King and Lenox 2002). Supporting this view, King and Lenox (2001a) found empirical evidence associating lean production adoption with environmental pollution reductions. In contrast, Rothenberg et al. (2001) found that lean firms are resistant to make large capital investments in the types of new technologies that often are required to improve environmental performance. Rothenberg et al.'s finding does not address a key tenet of lean, which is that capital investments often can be avoided as a result of capacity expansions generated through waste reductions—and that the waste that is reduced takes many forms, frequently including environmental and pollution waste (Yang et al. 2011). Additionally, many aspects of lean do not directly address environmental aspects of operations—for example, the adoption of U-shaped production lines might reduce the distance a worker walks within a facility, but it does not directly impact environmental performance (Shewchuk 2008). Despite the finding of Rothenberg et al., the prevailing theory supports a positive relationship between lean manufacturing initiatives and reductions in environmental waste. Therefore, our next hypothesis predicts:

H1$_b$ A leaner firm will be associated with lower environmental damages.

2.3 Environmental and firm performance

Firms that won environmental performance awards due to superior environmental strategies were found to experience positive increases in their market valuations (Klassen and McLaughlin 1996). Other studies typically have found a positive relationship between a firm's environmental performance and financial performance. Similarly, Dowell et al. (2000) found that firms experience higher levels of firm performance when they adopt more stringent environmental standards. Christoffersen et al. (2013) found a clear relationship between firm financial performance and environmental sustainability (assessed using the Newsweek Green Rankings) in the healthcare industry. Similarly, Murguia and Lence (2015) found that the stock market positively values firms ranked within the Newsweek Global 100 Green Rankings. This relationship also has been tested in a number of empirical studies: in two of the more widely cited studies both Hart and Ahuja (1996) and King and Lenox (2002) find lower emissions to be associated significantly with improved financial performance. From a higher-level policy viewpoint, research has demonstrated that, even when faced with stringent emissions regulations, firms with better environmental performance exhibit superior market performance (Kong et al. 2014). More recently, Tebini et al. (2015) found that superior environmental performance has a positive impact on firm performance in both the near-term and long-term.

The prevailing theory does support the idea that improved environmental performance leads to improved financial performance, but opposing views do exist. Both Walley and Whitehead (1994) as well as Kroes et al. (2012) suggested that efforts to improve environmental performance may be exceptionally expensive. Consequently, they suggested that environmental improvements will impact negatively a firm's financial performance.

At first glance, these conflicting viewpoints seem to add vagueness to the understanding of the relationship between environmental and financial performance. However, studies that predict that environmental damages negatively impact financial performance greatly outnumber those that postulate the contrasting view. Therefore, we adopt the more common view and predict that:

H1$_c$ Higher (lower) environmental damage correlates with lower (higher) firm financial performance.

2.4 Leanness, environmental performance, and firm performance

The relationships predicted between leanness, environmental damages, and financial performances are considered as separate independent relationships, as discussed previously. In actuality, there is likely some degree of interdependence between these relationships. Logically, we can expect that the negative influence of environmental damages might mediate the positive impact of lean on financial performance. Testing for the existence of this mediating relationship is noteworthy because of the nature of lean improvement efforts; lean typically does not target environmental wastes specifically, but rather lean addresses a variety of wastes within a firm (Hines and Rich 1997). Therefore, if our prior hypotheses hold true, finding that environmental damages mediate the effects of lean would imply that lean initiatives that do not target and reduce environmental damages directly are less impactful on financial performance than lean initiatives that result in decreased environmental damages. Therefore, our final hypothesis will assess if such interdependence is present:

H2 The positive relationship between leanness and firm financial performance is negatively mediated by environmental damages.

Taken together, our analysis of these proposed hypotheses will expand the understanding of the complex relationships between leanness, environmental damages, and financial performance using secondary data to ensure self-perception biases do not affect the relationships investigated.

3 Data, measures, and research methodology

3.1 Data sample

While the most closely related prior study used a survey, in contrast, our sample consists of publicly available annual financial and environmental data merged at the firm level. For this examination, we used Trucost's firm-level Total Environmental Damages measure (which is calculated in $USD) as a measure of environmental performance within firms. The firm-level financial data for publicly traded manufacturing firms (Standard Industry Classification Two-Digit Codes [SIC2] 20 through 39) included in our sample was retrieved from the COMPUSTAT database. To avoid presenting results influenced by outliers, after calculating the financial variables of interest, we winsorized our sample at the 1% level. The financial measures then were merged with the body of Trucost data available at the commencement of this study. This process resulted in an unbalanced panel sample that includes data from 389 publicly traded manufacturing firms, representing observations across 3337 firm-years, from the year 2002 through 2013.

Two drivers led us to focus this study on the manufacturing industry: (1) manufacturers generate a substantial share of the pollution emissions in the United States (approximately 25%) and (2) the level of manufacturing generated emissions have decreased dramatically since the 1980s, despite an increase in production output (Levinson 2009), which signals that waste reduction efforts, like those associated with lean efforts, actually can influence environmental performance in this industry. The descriptive statistics for the manufacturers in our sample, segmented by SIC2 industry groups, are presented in Table 1. Our sample includes firms in each of the SIC2 manufacturing groups, however approximately one-half of the firms and observations fall into three groups (SIC 28, 35, and 36). The largest of those subgroups, which includes the firms from chemical product industry (SIC 28), has been shown in prior studies to be the most pollution intensive manufacturing category (Letchumanan and Kodama 2000).

3.2 Dependent measure

Return on Assets (ROA) is a common barometer of a firm's financial health Meng et al. (2014). We calculated the ROA using publically available data from Compustat by dividing a firm's net annual income by the end of year total assets. ROA has been used widely as a measure of firm performance in a variety of environmental studies (Blomgren 2011; Tebini et al. 2015). Explicitly, we calculated ROA for firm k in period t as:

$$ROA_{kt} = \frac{Net\ Income_{kt}}{Total\ Assets_{kt}}$$

Table 1 Descriptive statistics by two-digit SIC code

2-Digit SIC	Industry title	# of firms in sample	# of observations	ROA Mean (SD)	Capacity leanness Mean (SD)	Total environmental damages (MM$) Mean (SD)	Employees (000's) Mean (SD)
20	Food and Kindred products	30	247	0.078 (0.05)	4.74 (2.25)	130.08 (380.79)	35.98 (42.38)
21	Tobacco products	3	28	0.123 (0.06)	6.26 (1.90)	61.54 (86.47)	55.66 (63.97)
22	Textile mill products	3	27	0.028 (0.06)	5.37 (1.68)	39.41 (41.67)	28.13 (18.14)
23	Apparel, finished products from fabrics and similar materials	7	63	0.096 (0.05)	8.29 (3.04)	5.12 (3.22)	22.35 (16.35)
24	Lumber and wood products, except furniture	5	29	0.042 (0.04)	1.53 (2.03)	258.76 (400.19)	16.09 (18.95)
25	Furniture and fixtures	6	52	0.050 (0.08)	7.98 (3.17)	9.34 (9.11)	27.33 (35.91)
26	Paper and allied products	12	133	0.052 (0.05)	2.85 (1.25)	320.48 (497.21)	30.50 (23.98)
27	Printing, publishing and allied industries	6	48	0.040 (0.05)	6.54 (4.89)	8.43 (15.36)	16.54 (21.15)
28	Chemicals and allied products	68	588	0.077 (0.08)	4.51 (3.72)	165.15 (400.51)	25.77 (31.17)
29	Petroleum refining and related industries	14	85	0.090 (0.05)	3.11 (2.25)	1367.73 (2568.05)	17.80 (24.33)
30	Rubber and miscellaneous plastic products	5	49	0.051 (0.06)	5.77 (3.30)	35.31 (41.85)	34.06 (26.52)
31	Leather and leather products	1	6	0.248 (0.03)	7.63 (1.22)	22.12 (12.64)	6.35 (3.82)

Table 1 continued

2-Digit SIC	Industry title	# of firms in sample	# of observations	ROA Mean (SD)	Capacity leanness Mean (SD)	Total environmental damages (MM$) Mean (SD)	Employees (000's) Mean (SD)
32	Stone, clay, glass, and concrete products	5	44	0.010 (0.09)	2.31 (1.29)	104.03 (85.19)	12.95 (9.54)
33	Primary metal industries	12	107	0.034 (0.07)	3.16 (1.47)	697.85 (1048.93)	22.18 (29.19)
34	Fabricated metal products, except machinery and transportation equipment	14	110	0.046 (0.04)	5.70 (1.62)	20.15 (26.87)	19.53 (17.42)
35	Industrial and commercial machinery and computer equipment	63	530	0.066 (0.06)	7.84 (4.95)	13.62 (31.09)	24.89 (31.16)
36	Electronic and other electrical equipment and components, except computer equipment	68	551	0.053 (0.09)	6.28 (5.67)	8.41 (12.54)	21.83 (31.27)
37	Transportation equipment	27	230	0.069 (0.06)	6.43 (3.30)	18.95 (26.45)	46.33 (58.30)
38	Measuring, analyzing, and controlling instruments; photographic, medical, optical goods; watches and clocks	40	366	0.079 (0.07)	7.33 (4.32)	9.95 (32.71)	20.07 (29.73)
39	Miscellaneous manufacturing industries	4	44	0.060 (0.05)	10.07 (5.80)	6.84 (3.52)	16.64 (12.38)
	Total	389	3337	0.066 (0.07)	5.90 (4.40)	120.80 (557.99)	26.00 (34.18)

3.3 Independent and control measures

We adopted an existing leanness calculation for this study. This measure compares a firm's sales revenue (S_{kt}) relative to the value of the firm's plant, property, and equipment (PPE_{kt}) (Kovach et al. 2015). Using this definition of leanness, a leaner firm will generate more sales using fewer resources; consequently a relatively leaner firm will exhibit a higher measure of *Leanness*.

Therefore, in this study, leanness for firm k in year t was calculated as:

$$Leanness_{kt} = \frac{S_{kt}}{PPE_{kt}}$$

For our environmental damage measures, we use data from the Trucost Environmental Register database, which represents the aggregated externality cost impact of a firm's air, land and water emissions and waste (Thomas et al. 2007). We used the value of a firm's total Environmental Damage (ED_{kt}) as a measure of environmental performance. This measure is an estimate of the emissions and waste levels within a firm, which is then used to determine the monetary impact of those emissions (Trucost 2009). Importantly, firms are permitted to review and revise these estimates directly with Trucost to ensure accuracy.

To ensure that firm damages are compared on a relatively equal basis in our analyses, we utilized the ratio of environmental damages (ED_{kt}) relative to annual sales (S_{kt}) rather than using the raw ED_{it} measure. Specifically, we utilized the following measure of total environmental damage for a firm:

$$Total\ Environmental\ Damage_{kt} = \frac{ED_{kt}}{S_{kt}}$$

A firm's size has been shown to impact financial performance in prior studies (Capkun et al. 2009; Eroglu and Hofer 2011). To adjust for differences in size across our sample, we use the number of employees within a firm as a proxy for firm size. The numbers of employees in the firms across our sample vary non-linearly with *ROA* and the Total Environmental Damages, therefore, we use the natural log of the number of employees in our study (Osborne 2005). In addition, to adjust for industry differences, the ROA, Leanness, and Total Environmental Damage measures were centered and standardized within each SIC2 grouping prior to our analyses to ensure comparability.

3.4 Research models

To evaluate the hypothesized relationships, we employed both unbalanced panel regression and pooled ordinary least squares (OLS) regression models. The unbalanced panel regression is well suited for this analysis, as our dataset represents a longitudinal sample taken over a 13-year period (Maddala and Lahiri 1992). The decision to replicate the analysis using OLS is motivated by two factors: First, consistency between the panel analysis and OLS will validate the robustness of our findings further. Second, the use of OLS facilitates the application of the Sobel–Goodman mediation test (as used in Zhu et al. 2013), which sheds insight into strength of any potential mediation effect (Baron and Kenny 1986).

The first model, which examines the relationship between leanness and financial performance ($H1_a$), is specified below (for brevity, we only present the panel regression specifications):

$$ROA_{kt} = \beta_0 + \beta_1 (Leanness_{kt}) + \beta_2 (Firm\_Size_{kt}) + \varepsilon_{kt} \quad (1)$$

Martin et al. (2012) found that climate friendly management policies correlate with higher productivity. We measure lean as sales over PP&E, which is analogous to having more productivity on a given set of property, plant, and equipment. Our second model, which tests the relationship between total environmental damages and leanness ($H1_b$) is specified as:

$$\begin{aligned} Total\_Environmental\_Damage_{kt} = \beta_0 + \beta_1 (Leanness_{kt}) \\ + \beta_2 (Firm\_Size_{kt}) + \varepsilon_{kt} \end{aligned} \quad (2)$$

The third model, which tests the hypothesized direct relationship between total environmental damage and financial performance ($H1_c$) is specified as:

$$\begin{aligned} ROA_{kt} = \beta_0 + \beta_1 (Total\_Environmental\_Damage_{kt}) \\ + \beta_2 (Firm\_Size_{kt}) + \varepsilon_{kt} \end{aligned} \quad (3)$$

The final model, which includes both leanness and total environmental damages as predictors of financial performance will be used to determine if environmental damages mediate the relationship between leanness and financial performance.

$$\begin{aligned} ROA_{kt} = \beta_0 + \beta_1 (Leanness_{kt}) + \beta_2 (Total\_Environmental\_Damage_{kt}) \\ + \beta_3 (Firm\_Size_{kt}) + \varepsilon_{kt} \end{aligned} \quad (4)$$

As stipulated in Baron and Kenny's (1986) seminal work on mediation, total environmental damage can be shown to function as a mediator if the following conditions are satisfied (assuming a significant direct relation is found between leanness and financial performance in Model 1): (1) variations in leanness significantly predict variations in total environmental damage (Model 2), (2) variations in total environmental damage significantly predict variations in financial performance (Model 3), and (3) the relationship between leanness and financial performance diminishes when total environmental damages are also included as a predictor in the model (Model 4). Total environmental damages can be assumed to be the unique mediator if the relationship between leanness and firm performance becomes insignificant in Model 4; however, if the relationship between leanness and firm performance remains significant, total environmental damages is said to partially mediate the relationship, which implies that other mediators potentially exist.

For the panel regressions, Hausman tests were conducted for each model to determine the appropriateness of either a fixed-or random-effects specification. All of the

Table 2 Pairwise correlation analysis

N=3386	Return on assets	Leanness	Total environmental damage	Firm size
Return on assets	1.0000			
Capacity leanness	0.0795***	1.0000		
Total environmental damage	− 0.0833***	− 0.1286***	1.0000	
Firm size	0.0297	− 0.0867***	0.0021	1.0000

3337 annual observations from 389 firms
All correlations with *** are significant at 0.01 or below

tests indicated that the unique errors were correlated with the regressors, which dictates the use of fixed effects models (Greene 2008). Additionally, we computed the Variance Inflation factors (VIF) for each model to validate that multicollinearity is not influencing the findings; all of the VIF scores were found to be well below the recommended threshold of 10 (Cohen et al. 2003). The empirical results of our analyses are presented in the following section.

4 Empirical results

The results of a pairwise correlation analysis are presented in Table 2. For capacity leanness, we find a positive correlation with financial performance (ROA) and a negative relationship with total environmental damage. Total environmental damage is negatively correlated with financial performance (ROA). Firm size (i.e. employees) is correlated significantly and negatively with leanness, which lends justification to its inclusion as a control in our regression models.

The results of the first analyses, presented as Model 1 in Tables 3 and 4 (respectively for the panel and OLS regressions), both find leanness to be associated significantly and positively with financial performance (ROA). The consistency of these two models indicates support for $H1_a$. The second hypothesis, tested with Model 2 (Tables 3, 4), finds a significant negative relationship between leanness and total environmental damages (across both methodologies)—demonstrating support for $H1_b$. Model 3 finds a significant negative relationship between total environmental damage and ROA in both the panel and OLS regression analyses, supporting $H1_c$.

The final analysis, testing if total environmental damages mediate the relationship between leanness and financial performance, is conducted utilizing Model 4 (Tables 3, 4) as well as the Sobel–Goodman mediation tests presented in Table 5. Both the panel and OLS models show that total environmental damages are associated significantly (and negatively) with ROA when leanness is included in the model—however, in both analyses leanness remained significantly associated with ROA, which implies that total environmental damages partially mediate the relationship between leanness and financial performance. Further supporting this finding, the Sobel–Goodman tests indicate that total environmental damages significantly, but only partially, mediate the

Table 3 Panel analysis regression

Independent variables	Model 1: ROA on leanness and size	Model 2: total environmental damage on leanness and size	Model 3: ROA on total environmental damage and size	Model 4: ROA on leanness, total environmental damage, and size
Leanness	0.0268*** ($H1_a$) (0.00204)	− 0.0494** ($H1_b$) (0.0195)		0.0266*** (H2) (0.00205)
Total environmental damage			− 0.00555*** ($H1_c$) (0.00198)	− 0.00439** (H2) (0.00193)
Firm size	− 0.00258 (0.00320)	0.00672 (0.0306)	− 0.00134 (0.00329)	− 0.00255 (0.00320)
Intercept	0.0597*** (0.00824)	0.00828 (0.0787)	0.0691*** (0.00843)	0.0597*** (0.00823)
Observations	3337	3337	3337	3337
Number of firms	389	389	389	389
R-squared	0.055	0.002	0.005	0.057
F test	85.83***	3.198***	4.03***	59.03***

Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 4 Pooled ordinary least squares regression

Independent variables	Model 1: ROA on leanness and size	Model 2: total environmental damage on leanness and size	Model 3: ROA on total environmental damage and size	Model 4: ROA on leanness, total environmental damage, and size
Leanness	0.00499***($H1_a$) (0.00104)	− 0.109*** ($H1_b$) (0.0145)		0.00441*** (H2) (0.00105)
Total environmental damage			− 0.00598*** ($H1_c$) (0.00124)	− 0.00531*** (H2) (0.00125)
Firm size	0.00210** (0.000985)	− 0.00718 (0.0137)	0.00170* (0.00981)	0.00206** (0.000982)
Intercept	0.0580*** (0.00288)	0.0716* (0.0399)	0.0614*** (0.00279)	0.0584*** (0.00287)
Observations	3337	3337	3337	3337
R-squared	0.008	0.017	0.008	0.013
F test	12.88***	28.17***	13.15***	14.68***

Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

relationship between leanness and firm performance. Specifically, these tests estimate that total environmental damages mediate approximately 12% of the effect of leanness on ROA. Combined, these findings provide some measure of support for H2.

Table 5 Sobel–Goodman mediation tests

	Coefficient	Z-score	$p > \|Z\|$
Sobel	0.00057	3.842	0.00012
Goodman-1 (Aroian)	0.00057	3.816	0.00014
Goodman-2	0.00057	3.868	0.00011

Proportion of total effect that is mediated: 0.121

5 Conclusions

This study adds to the extant literature by using secondary empirical data rather than primary data (self-perception surveys). We utilized a sample of firm performance data merged with environmental performance data, provides a new view on the relationships between firm leanness, environmental damages, and financial performance. One of the key contributions is the validation of the proposition that lean initiatives may improve both financial and environmental performance. Although these results may seem intuitive, as discussed earlier in the paper, prior research has either found mixed results regarding the relationship between environmental improvements and financial performance or was based on perceptions of a survey respondent. We believe that our tests of these relationships, conducted using empirical environmental damage data and financial data, should give managers confidence that lean can improve both the environmental and financial performance simultaneously. A second key contribution of this study is the new insight that environmental damages can mediate partially the impact of lean on financial performance.

These findings have several important implications from a managerial perspective. First, the results show that while lean efforts in a firm can improve financial performance significantly, efforts that target the reduction of environmentally damaging waste will have a more pronounced impact on financial performance. A manager would be wise to target reducing environmental damage through lean initiatives not only because such efforts are socially responsible but also because these initiatives will improve the bottom line. Conversely, the benefits of waste reduction efforts that do not impact environmental damages may be muted within firms that produce high levels of pollution.

Several aspects of this study may be viewed as limitations to the generalizability of the findings. First, the number of firms for which environmental damage data is available is substantially smaller than the number of firms for which financial data is publicly reported—on the surface, this circumstance may appear to limit the significance of the findings, however, our final sample of nearly 400 firms represents a broad swath of the manufacturing industry. As a practical matter, Trucost chose to collect and develop environmental damages for the largest companies only (average annual assets of $12.7 billion versus entire financial dataset with average annual assets of $3.6 billion), which makes our analysis more of a prescription for larger manufacturers, and of interest to smaller manufacturers to consider. Future studies that can obtain detailed environmental information for smaller public manufacturing firms and private firms could extend this research to a broader universe of manufacturing companies.

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