Pontifícia Universidade Católica
do Rio de Janeiro

Renata Bianchini Magon

Sustainability impact on manufacturing operational performance: an empirical investigation

Dissertação de Mestrado

Dissertation presented to the Programa de Pós-Graduação em Engenharia de Produção of the Departamento de Engenharia Industrial, PUC-Rio, as partial fulfillment of the requirements for the degree of Mestre em Engenharia de Produção.

Advisor: Prof. Antônio Márcio Tavares Thomé

Co-advisor: Prof. Rui Manuel Soucasaux Meneses e Sousa

Rio de Janeiro
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To my family,
for their support, encouragement,
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Abstract

Bianchini Magon, Renata; Thomé, Antônio Márcio Tavares; Sousa, Rui Manuel Soucasaux Meneses. **Sustainability impact on manufacturing operational performance: an empirical investigation**. Rio de Janeiro, 2017. 102p. Dissertação de Mestrado - Departamento de Engenharia Industrial, Pontifícia Universidade Católica do Rio de Janeiro.

Companies worldwide realized that being committed to sustainability is becoming a source to competitive advantage. Empirical evidence exists in the literature validating a positive link of sustainable manufacturing practices with organizational performance. However, there is a lack of rigorous empirical studies directly examining the impact of both environmental and social practices on operational manufacturing performance, especially in four main competitive operational capabilities: cost delivery, quality, and flexibility. This study analyses these relationships with literature review and the backdrop of the resource-based view and of the natural resource-based view of the firm. For this purpose, structural equation modeling (SEM) is used to build the measurement model and hierarchical stepwise multiple regression is used to test the research hypotheses. The data used were obtained from the sixth round of the International Manufacturing Strategy Survey (IMSS-VI) which includes responses from 931 manufacturing plants within the assembly industry in 22 countries. Our findings suggest that internal and external sustainability management practices are complementary. Manufacturing plants can increase their quality and flexibility performance, by implementing internal sustainable practices, such as water and energy consumption reduction, environmental and social certifications, work/life balance policies and sustainability communication, and can increase their cost efficiency and delivery performance by promoting supplier's sustainability management. Overall, this study contributes to the investigation of strategies for sustainable management, highlighting important implications for both practice and future research.

Keywords

Sustainability; sustainable practices; operational performance; operations management; literature review; structural equation modeling; multivariate regression.

Resumo

Bianchini Magon, Renata; Thomé, Antônio Márcio Tavares; Sousa, Rui Manuel Soucasaux Meneses. **Impacto da sustentabilidade no desempenho operacional da manufatura: uma investigação empírica.** Rio de Janeiro, 2017. 102p. Dissertação de Mestrado - Departamento de Engenharia Industrial, Pontifícia Universidade Católica do Rio de Janeiro.

Dado o surgimento de uma nova ordem econômica, as empresas em todo o mundo perceberam que precisam estar comprometidas com a sustentabilidade. As pressões externas vão desde o governo, com a criação de regulamentações socioambientais, até os empregados e a sociedade - mídia, ONGs e clientes - que estão cada vez mais conectados, atentos e exigentes a essas questões. Empresas sustentáveis devem satisfazer as necessidades do presente (gerar lucro) sem comprometer o futuro (respeitando o meio ambiente e os preceitos de responsabilidade social).

A indústria de manufatura, foco dessa dissertação, tem muito a contribuir para a sustentabilidade, pois impacta socio-economico-ambientalmente os locais onde opera, de forma significativa. Geração de gases de efeito estufa e de resíduos tóxicos estão entre os grandes vilões, mas não se limitando a eles. No âmbito interno, as empresas necessitam absorver o conceito de sustentabilidade no seu processo de produção, a partir de práticas de gestão ambiental relacionadas, por exemplo, à otimização do uso dos recursos ambientais (ex. reuso de água e utilização de energias alternativas), à redução de gases poluentes e às alternativas para descarte de resíduos; assim como às práticas de gestão social tais como medidas para aumentar saúde e segurança no ambiente de trabalho e criação de programas ligados ao bem estar dos funcionários. As ações, porém, devem ser ampliadas para toda a cadeia do processo e devem ser adotadas medidas colaborativas com os fornecedores para que sejam comprometidos e também responsáveis. No entanto, para a empresa se tornar sustentável, investimentos adicionais e aumento de custos são necessários para incluir em sua estrutura pessoal e processos responsáveis pelo incremento da sustentabilidade, seja ela econômica, social ou relacionada ao meio ambiente, o chamado *triple bottom line*, em inglês.

Por outro lado, o estímulo ao processo criativo, tanto de seus funcionários quanto de seus colaboradores, e a busca constante por soluções eficazes e eficientes, que gerem o menor impacto social e ambiental possível, acabam por criar oportunidades de negócios e, muitas vezes, melhorar índices de performance, sejam financeiros, operacionais ou ambientais. Esse “ganha-ganha” tem sido demonstrado em diversos estudos de pesquisa empírica no meio acadêmico, porém alguns resultados ainda são contraditórios. Pesquisas relacionadas a esse tema têm aumentado na última década, especialmente no campo da gestão de produção e operações, porém ainda se concentram especialmente nas questões ambientais, havendo limitações de estudos que consideram práticas sociais da sustentabilidade de forma conjunta. Assim como carece de mais estudos que analisem o impacto das práticas sustentáveis em indicadores operacionais, tais como custo, prazo de entrega, flexibilidade e qualidade.

Portanto, essa dissertação tem como principal objetivo aumentar o entendimento dos efeitos da gestão interna e externa da sustentabilidade (social e ambiental) nos indicadores operacionais da manufatura, através de uma pesquisa empírica. Para isso, três perguntas de pesquisa foram desenvolvidas: (a) Como a pesquisa empírica tem analisado os modelos causais de sustentabilidade? (b) Como a Gestão de Operações define sustentabilidade? e (c) Como práticas de sustentabilidade impactam o desempenho operacional da manufatura? As respostas às primeiras duas perguntas, através de uma revisão de literatura, fornecem uma visão holística dos fatores que influenciam a relação de sustentabilidade e desempenho da empresa, além de conceitos e insumos teóricos para a construção de construtos e de hipóteses que atenderão à terceira pergunta.

As hipóteses sobre as relações entre sustentabilidade e desempenho operacional foram fundamentadas, especialmente, na teoria da visão baseada em recursos da empresa (RBV, na sigla em inglês) e na sua extensão, a visão baseada em recursos naturais (NRBV, na sigla em inglês). A validação dos construtos e do modelo de mensuração foi feita a partir de análise fatorial confirmatória, umas das técnicas estatísticas da modelagem de equações estruturais (SEM, na sigla em inglês), em *software* AMOS 22.0. A base de dados utilizada é da 6ª edição da *International Manufacturing Strategy Survey* (IMSS-VI), com a participação de 22 países e 931 empresas. Finalmente, as hipóteses foram testadas através da técnica de regressão linear múltipla hierárquica.

Os resultados sugerem que as práticas internas e externas ligadas à sustentabilidade são complementares. Enquanto práticas internas de gestão ambiental e social internas (i.e. certificação ambiental e social, redução de consumo de água e energia, políticas sociais, comunicação e treinamentos internos orientados para sustentabilidade) promovem melhoria nos indicadores de qualidade e flexibilidade, práticas externas de colaboração com os fornecedores contribuem para a redução de custos operacionais e para a melhoria nos índices de entrega. Ou seja, a busca pela sustentabilidade nos processos e na cadeia produtiva não deve ser encarada de forma míope, passível de aumento de custos no curto prazo, ou como uma obrigação para atender uma legislação, mas sim como uma vantagem competitiva. Este estudo, portanto, contribui para atuais debates sobre como a sustentabilidade impacta no desempenho operacional da manufatura, tornando os resultados de interesse não apenas para acadêmicos, mas também para praticantes na área.

Palavras-chave

Sustentabilidade; práticas sustentáveis; desempenho operacional; gestão de operações; revisão da literatura; modelagem de equações estruturais; regressão multivariada.

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List of acronyms

ADF – Asymptotically distribution free

AMOS – Analysis of Moment Structure (*software*)

AVE – Average variance extracted

CFA – Confirmatory Factor Analysis

CFI – Comparative Fit Index

CI – Confidence Interval

CR – Composite reliabilities

CSR – Corporate Social Responsibility

EM – Environmental Management

EMS – Environmental Management Systems

EXT_SUST – External Sustainability Management

GDP – Gross Domestic Product (per capita)

GOF – Goodness Of Fit

GSCM – Green Supply Chain Management

INT_SUST – Internal Sustainability Management Practices

IMSS – International Management Strategy Survey

IMSS-VI – Sixth Round of International Management Strategy Survey

IT – Information Technology

JIT – Just In Time

ML - Maximum Likelihood

NFI – Normed Fit Index

NRBV – Natural Resource Based View

OM – Operations Management

RBV – Resource Based View

RMSEA – Root Mean Square Error of Approximation

RQ – Research Question

SEM – Structural Equation Modeling

SPSS – Statistical Package for the Social Sciences

SC – Supply Chain

SLR – Systematic Literature Review

SSCM – Sustainable Supply Chain Management

TLI – Tucker Lewis Index

TQM – Total Quality Management

WLS – Weighted Least Square

WoS – Web of Science

1
Introduction

The relevance of sustainability is prevalent and expected to increase further due to economic, societal and ecological concerns. Societies' pursuit of unlimited economic growth, overconsumption, population growth, environmental degradation, and climate change are inserting sustainability concerns at the forefront of contemporary societies (Schoenherr, 2012). Sustainability can be defined as a multi-dimensional concept comprised of the triple bottom-line of economic, environmental, and social aspects (Elkington, 1998). From a business perspective, profits are no longer the only measure of a company's performance: the improvement in ecological and social systems are equally paramount to gaining competitive advantage (Gladwin et al., 1995, Starik and Rands, 1995; Jennings and Zandbergen, 2005; Pagell and Gobeli, 2009). Sustainability is becoming a key imperative, crucial to the long-term survival of any company (Hay et al., 2005; Kleindorfer et al., 2005; Longoni et al. 2014). However, many companies have not implemented the necessary changes into their policies, decision making procedures and performance evaluation to fully realize the benefits of sustainability management (Chang and Kuo, 2008; Longoni et al., 2014) due to historical and theoretical reasons.

Historically, companies have been mostly worried about compliance with laws and regulations, restricting sustainability concerns to environmental issues (Sarkis, 2001; Gimenez et al., 2012). Until recently, the prevailing wisdom among researchers and managers alike supported the existence of a trade-off between costs and environmental protection that would harm rather than improve firms` performance (Angell and Klassen 1999, Feldman et al., 1997). In a context of economic crisis, operations managers tend to narrowly focus on cost reduction, within the realm of a "short-term culture" (Miles, 1993; Gigler et al., 2014; Buil et al. 2016). Implementing waste recycling programs, training employees, and subscribing to certifications require significant capital disbursement and costly changes to production processes and equipment (Cruz and Wakolbinger, 2008; Gimenez et al., 2012; Adebanjo et al., 2016).

Porter (1991) was among the first in the literature to challenge the common sense that complying with regulations is harmful to the competitiveness of firms. Porter argued that new environmental standards in fact lead to innovation and that the resulting benefits may offset the cost of implementing environmental management practices (Montabon et al., 2007). Subsequently, empirical research to investigate if greening the company would pay off arose (Chang and Kuo, 2008; Pagell and Gobeli, 2009). Porter and van der Linde (1995a, 1995b) used examples from several companies to show that environmental improvements can lead to improved processes, products, and profits. Many studies have found that promoting sustainability leads to competitive advantages (e.g. Russo and Fouts 1997; Christmann, 2001; Melnyk et al., 2003; Pagell et al. 2004; Rao and Holt, 2005; Montabon et al., 2007; Yang et al., 2010; Huang et al., 2012; Green et al. 2012a).

Nonetheless, the win/win situation of a positive correlation between improved sustainability and performance met with mixed results in empirical research (Wagner et al., 2001; Zhu and Sarkis, 2004; Graham and Potter, 2015; Szasz et al., 2016; Adebanjo et al. 2016). Some authors found a negative effect of sustainability practices adoption on overall firms' performance (e.g. Hart and Ahuja, 1996; Montabon et al., 2000; Rao and Holt, 2005; Paulraj and De Jong, 2011; De Giovanni, 2012; Dam and Petkova, 2014). These contradictory results are at least partly due to the use of different constructs and of different operational measures of sustainability (Azevedo et al., 2011; Wu and Pagell, 2011; Adebanjo et al., 2016) and also because sustainability effects may have a time lag.

From a theoretical standing point, companies are more recently enlarging the trade-off perspective, embracing other manufacturing operational performance beyond costs, such as quality, delivery and flexibility (Montabon et al., 2000), and reaching for sustainability beyond factory walls and into the global supply chain (Golini et al., 2014). In additional, under the influence of regulators, consumers and pressure groups, the concept of sustainability evolved from a narrow environmental view to embrace social and economic sustainability as well (WCED, 1987; WSSD, 2002; Kates et al., 2005). In this regard, the manufacturing industry is in a particular position to contribute to sustainability, as it employs large contingents of workers and operates in areas often exposed to chemicals, toxic wastes or polluting gases (Sarkis, 2001; Gimenez et al., 2012; Bhadauria et al., 2014). Despite the ever-growing relevance of sustainability, there are still few empirical studies addressing the link between sustainability management practices and multiple dimensions of manufacturing operational performance. Furthermore, until recently there has been little research distinguishing between internal and external sustainability practices (e.g. Gimenez et al, 2012) as well as considering the combined effect of both environmental and social management practices of sustainability upon multi-dimensional measures of operational performance (e.g. Pullman et al., 2009; Wiengarten et al., 2012).

Therefore, a primary objective of this study is to complement recent literature in sustainability by measuring the impact of internal and external sustainability management practices, encompassing social and environmental dimensions, on manufacturing operational performance. For this purpose three research questions (RQs) were developed:

i) How empirical research analyses causal models of sustainability?
ii) How Operations Management (OM) defines sustainability?; and
iii) How sustainability practices impact manufacturing operational performance?

The answers to the first two RQs will provide a theoretical basis and a comprehensive view of the factors that influence the relationship between sustainability and performance. To answer the third RQ, statistical techniques will be used and applied to International Management Strategy Survey (IMSS) database. Structural equation modeling offers tools for empirical theory development and construct validation. Hypotheses will be tested using hierarchical stepwise multiple regression.

These procedures intend to contribute to increase the knowledge about the relationships between sustainability management practices and manufacturing operational performance in important ways. First, by analyzing the sustainability-performance relationships with the backdrop of the resource-based-view (RBV) of the firm (Barney, 1991) and its extension to the natural RBV (NRBV) (Hart, 1995). This theoretical lens is important to stress the unique and inimitable resources that contribute to the effect of sustainability on performance. Second, by defining sustainability as two complex constructs: one covering internal sustainability management practices and the other comprising external sustainability management, both embracing social and environmental practices. Internal practices include environmental and social certifications, communications, energy and water programs, and work/life balance policies. External sustainability management focused on suppliers' collaboration, including supplier training/education in sustainability issues and joint efforts with suppliers to improve their sustainability performance. Third contribution is offering a multi-dimensional analysis of manufacturing operational performance, by examining cost, quality, flexibility and delivery dimensions. Finally, this study empirically tests the sustainability-performance relationship using a large international dataset comprised of 931 manufactures from 22 countries, controlling for the country's economic development, firm size and market volatility, so the contribution can be generalized to a large number of sectors, countries and market dynamics.

The dissertation is divided in six chapters, being this first one the introduction. The second chapter presents a bibliographic analysis, refers to basics of sustainability with key definitions and theoretical background to formulate the individual constructs, research model and hypotheses to be tested. Chapter three presents the data and methods used in data analysis. Chapter four displays the measurement model assessment and regression results. Chapter five discusses the results. Finally, the main conclusions and suggestions for future research are presented in Chapter six.

2
Theoretical Foundations: definitions and basics concepts

This chapter intends to answer two RQs – (i) How empirical research analyses causal models of sustainability and performance? and (ii) How OM defines sustainability?

Section 2.1 comprises the methods and basic statistics from the literature review of empirical research that links sustainability to performance. Scrutinizing a final sample of 186 papers, the author analyses the causal/structural models on sustainability, showing prevalent factors in recent empirical research that directly or indirectly impact performance. In this section, the author also presents a synthesis of empirical studies that analyzed specifically the impact of environmental and/or social practices on the manufacturing operational performance of the firm.

Section 2.2 offers an OM perspective of sustainability and also provides theoretical basis to motivate the elaboration of the hypotheses. The fundamental concepts of the resource-based view of the firm (RBV) and the natural resource-based view of the firm (NRBV) are analyzed with an emphasis on the direct effects of sustainability practices on performance.

Section 2.3 presents conceptual background to define individual constructs of sustainability to be used in this dissertation. Empirical studies that also guided the theoretical foundation are pointed out. In this section, the hypotheses are elaborated in order to answer the third research question (How sustainability practices impact manufacturing operational performance?).

2.1
Empirical research on the impact of sustainability on performance

The search and selection of studies to answer the first research question ("How empirical research analyses causal models of sustainability and performance?") and support the bibliographic analysis for theoretical basis followed the second step ("search and selection of databases and articles") of the eight steps approach proposed in Thomé et al. (2016a) for systematic literature reviews (SLRs). The search and selection steps are:

(i) Bibliographic database or journals selection;
(ii) Keywords search,
(iii) Review of selected abstracts,
(iv) Application of criteria for inclusion/exclusion of studies,
(v) Full-text review of selected papers,
(vi) Backward search, and
(vii) Forward search in retrieved papers.

Scopus and Web of Science (WoS) databases were chosen for keyword search, due to their extensive coverage of thousands of journals from major publishers of peer-reviewed papers, such as Springer, Elsevier and Emerald (Thome et al., 2016b). Although Scopus database covers a wider journal range compared to WoS, it is limited to more recent papers. Hence, the two databases complement rather than replace each other (Falagas et al., 2008).

The search was carried out in two different periods. The analysis of the causal models in sustainability (determinants, moderator, mediator and performance) reports data retrieved from both Scopus and WoS up to September 2016. The descriptive statistics on "year of publication", "authors", "source" and "subject area" were updated until June 2017, restricted to Scopus. WoS was not included in the descriptive statistics analysis considering it classifies subject areas differently than Scopus.

The keywords were adapted to the search engines of the databases and applied to titles, abstracts and article keywords. Documents were restricted to articles, articles in press and reviews, with no limitation on publication dates. In an attempt to answer the first RQ ("How empirical research analyses causal models of sustainability and performance?"), the database search used the following keywords, in pseudo-code: (TITLE-ABS-KEY (sustainab*) AND TITLE-ABS-KEY("structural equation model*" OR "stepwise regression" OR "step-wise regression" OR "hierarchical regression" OR "path analysis") AND TITLE-ABS-KEY(performance)).

The first title-abstract-keywords expression limited results to the theme of sustainability. The second expression limited results to empirical research that used statistical techniques. The third, limited results that linked sustainability to any performance outcome in the firm.

This keyword search in Scopus resulted in 314 documents. The evolution of the number of documents shows a significant increase of this topic in the past three years. In the year of 2014 there were 39 documents, in 2015 there were 58, in 2016 there were 71, and in 2017 there are already 34 (see Figure 1). Regarding the papers' geographical location, most publications were from USA, with 56 publications in the area, followed by China, with 41 publications, and Malaysia, with 36 publications, to mention a few. Concerning the source of these publications, the Journal of Cleaner Production was the most represented with 19 documents. Table 1 shows the top ten journals from this selection and the number of documents associated to them. It is interesting to remark that five of these journals are related to Operations Management. The subject areas of the documents shown in Figure 2 confirm that they are prevalent in the OM field, with 61,1% of these documents related to the "Business, Management and Accounting" area.

Table 1: Top Ten journals from the literature search

Journals	**N**
Journal of Cleaner Production *	19
Sustainability Switzerland	14
International Journal of Operations & Production Management*	8
International Journal Of Production Research*	7
Asian Social Science	5
Business Strategy And The Environment	5
Corporate Social Responsibility And Environmental Management	4
Industrial Management And Data Systems*	4
International Journal Of Applied Business And Economic Research	4
Journal Of Supply Chain Management*	4

Source: Scopus database (June, 2016)

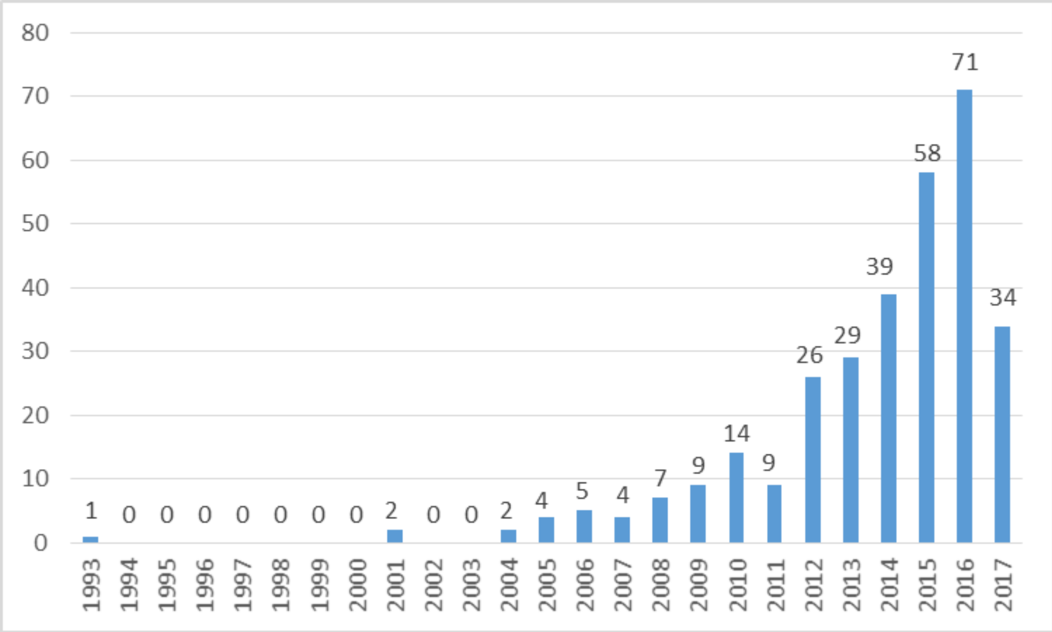

Figure 1: Number of documents per year of the literature search
Source: Scopus database (June 2016)

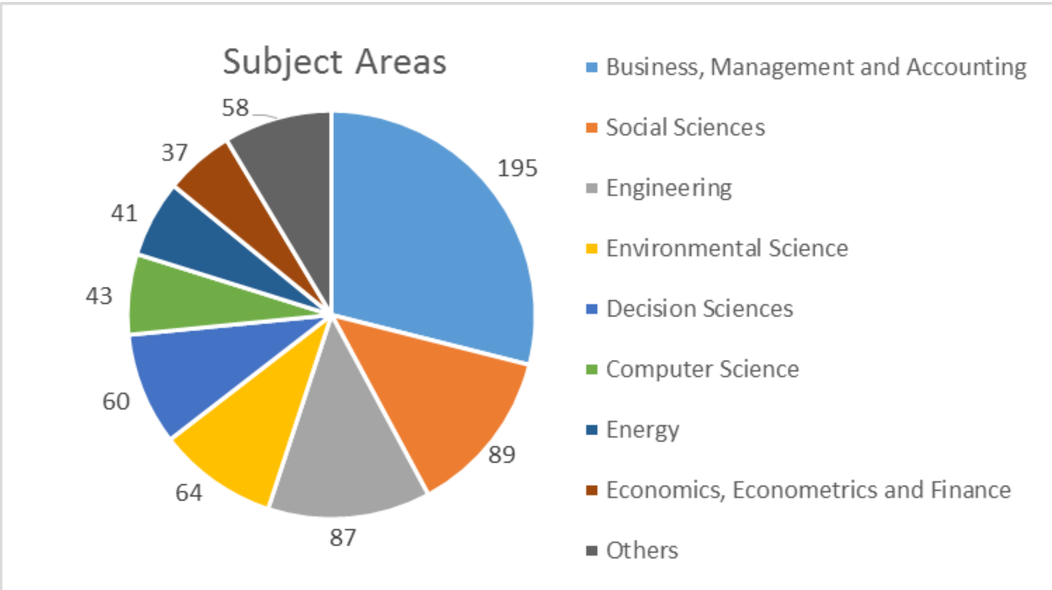

Figure 2: Subject areas by documents in sustainability-performance empirical research
Source: Scopus database (June 2016)

According to this dissertation’s search, the most prolific and influential authors in the empirical research linking sustainability and performance are Green, K.W. (5 articles; h-index 26); Beneditez-Amado, J. (4 articles; h-index 8) and Toms, L. (4 articles; h-index 4). The other authors published three articles or less (see Table 2 with main authors).

It is noteworthy that Green, Toms and Clark are frequent co-authors. Green et al. (2012b) studied the impact of green supply chain management practices on performance indicators, such as environmental and operational. Green et al. (2015) studied the impact of market orientation on environment sustainability strategy. Clark et al. (2014) verified the moderation effect of market orientation sustainability in stakeholder involvement. They also participated in studies regarding the impact of green information systems on performance (Bhadauria et al., 2014; Meacham et al., 2013).

Benitez-Amado focused on information technology (IT) and empirically analyzed the influence of IT on environmental performance (Wang et al., 2015) and the impact of IT on talent management and operational environmental sustainability (Benitez-Amado et al., 2015). This author also studied the relationship between IT infrastructure leveraging, talent management and operational sustainability, and their effects on the business value of the operations strategy (Benitez-Amado et al., 2013). Finally, an analysis engrained on the resource-based view of the firm addressed the relationships between IT, environmental organizational issues and firm performance (Benitez-Amado and Walczuch, 2012).

Table 2: Main authors in sustainability-performance empirical research

Authors	# of papers	h-index	University	Country
Green, K.W.	5	26	Southern Arkansas University	USA
Benitez-Amado, J.	4	8	Universidad de Granada	Spain
Toms, L.C.	4	4	Southern Arkansas University	USA
Zhu, Q.	3	32	Shanghai Jiaotong University	China
Jabbour, C.J.C.	3	19	University of Stirling	United Kingdom
Lu, C.-S.	3	19	National Kaohsiung Marine University Taiwan	Taiwan
Cagliano, R.	3	18	Politecnico di Milano	Italy
Paulraj, A.	3	15	Manchester Business School	United Kingdom
Choi, Y.	3	11	Inha University	South Korea
Bhadauria, V.S.	3	5	Southern Arkansas University	USA
Meacham, J.	3	4	Southern Arkansas University	USA
Warokka, Ari	3	1	Universidad Autonoma de Madrid	Spain

The search on both databases (Scopus and WoS), after duplicates were removed, returned 409 documents. After the abstracts were thoroughly reviewed by the author and the dissertation's advisor, 246 papers were selected for full-text review. The review process was interactive and resulted in high level of agreement, checked with inter-code reliability (Thomé, 2014). Percentage agreement was 95% and average pairwise Cohen's kappa, Fleiss's kappa and Krippendorff's alfa were equal 0.87, well above 0.81 threshold level for Krippendorff's alfa, indicating good agreement among different evaluators (see Figure 3). The exclusion criteria rejected studies that did not meet the following conditions: (i) be an empirical research using statistical techniques to analyze causal models, (ii) investigate sustainability variables as determinant and/or mediator and/or moderator and/or performance (iii) English or Portuguese language.

Following, 168 full text articles were assessed for eligibility. Subsequently, backward and forward searches were performed and 18 articles were included, resulting in a total of 186 final papers for analysis. Figure 4 depicts these results in PRISMA 2009 Flow Diagram. PRISMA stands for preferred reporting items for SLRs and meta-analysis (http://www.prisma-statement.org) (Moher et al., 2009).

ReCal 0.1 Alpha for 3+ Coders
results for file "round 2-dois juizes.csv"

File size:	1230 bytes
N coders:	2
N cases:	246
N decisions:	492

Average Pairwise Percent Agreement

Average pairwise percent agr.	Pairwise pct. agr. cols 1 & 2
95.122%	95.122%

Fleiss' Kappa

Fleiss' Kappa	Observed Agreement	Expected Agreement
0.878	0.951	0.6

Average Pairwise Cohen's Kappa

Average pairwise CK	Pairwise CK cols 1 & 2
0.878	0.878

Krippendorff's Alpha (nominal)

Krippendorff's Alpha	N Decisions	$\Sigma_c o_{cc}$***	$\Sigma_c n_c(n_c - 1)$***
0.878	492	468	144740

***These figures are drawn from Krippendorff (2007, case C.)

Figure 3: Intercodes reliability rates

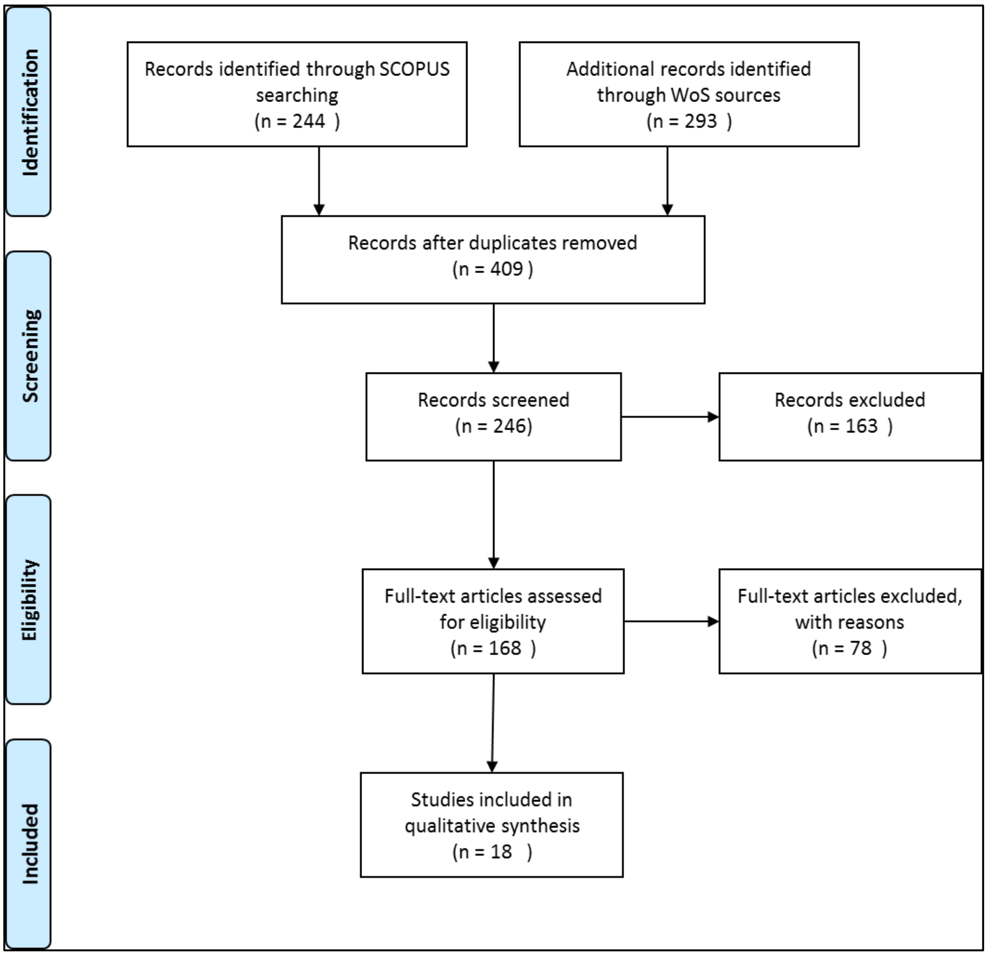

Figure 4: Prisma Flow Diagram 2009

After completing the search and document selection, the author was able to organize information related to the causal model of sustainability and performance, including variables that can influence positively or negatively performance, so-called determinants, and variables that can mediate (mediators) and/or moderate (moderators) the relationship being studied.

Table 3 depicts the top five determinants that can influence positively or negatively the relationship between sustainability and performance. Table 4 depicts the main variables or constructs that mediate this relationship. Table 5 shows the variables found within the selected articles of this dissertation that moderate the relationship between sustainability and performance. The most mentioned performance indicators are in Table 6. This information provide foundation for theory development and future research on sustainability in an attempt to investigate which variables have been associated in the past to the link with sustainability and performance.

The determinant quoted most frequently in Table 3, with 41 studies, was *internal sustainability management practices*, which encompass environmental and/or social practices. Most of the papers (32), though, focused only on environmental practices and some authors would call it *internal green supply chain management* (internal GSCM), which is the implementation of environmental management practices within a company (Rao and Holt, 2005; Vachon and Klassen, 2006; Yu et al., 2014). GSCM practices comprise a set of green activities in product development, procurement, production/manufacturing, distribution and reverse logistics (Golini et al., 2014, Chin et al., 2015). Some acknowledged practices, in the literature, were pollution and waste reduction; energy and water saving; recycling, reuse and use of alternative, green purchasing, green packing, eco-design and environmental certification. In a social dimension, social certification and health & safety were practices often mentioned in the literature.

The number of papers that examined environmental practices was still significantly higher than the number of papers that examined both environmental and social practices, confirming the need to increase research in both dimensions of sustainability.

Internal sustainability management practices were often presented as a single construct (e.g. Rao and Holt, 2005; De Giovani, 2012; Green et al, 2012b; Yu et al. 2014; Adebanjo et al. 2016; Jabbour et al., 2016;), although they can also be analyzed separately (e.g. Schoenherr, 2012). In this dissertation, when more than two internal sustainable practices were analyzed, aggregately (as a single construct) or separately, they were reported under *internal sustainability management practices* in Table 3.

Another lead-determinant was *external sustainability management*, with 32 studies, which consists of supply chain (SC) collaboration, SC integration and SC mutual trust. Yu et al. (2014, p.685), among other authors, called it *External Green Supply Chain Management* (external GSCM) and defined external GSCM as “the direct involvement of an organization with its suppliers and customers in planning jointly for GSCM initiatives and environmental management practices (...) All these activities, related to supply chain management, require varying degrees of integration with supply chain partners, either upstream with suppliers or downstream with customers”.

Human resources management towards sustainability, which included top management support, employees engagement and personnel training (22 studies), *pressures* from customer, competitor, legislation, regulation, government policies, among others (15 studies), and *social responsibility / CSR – corporate social responsibility* (8 studies) were the other main determinants in the relationship between sustainability and performance. Other factors had seven studies or less.

Table 3: Main determinants in sustainability-performance empirical research

Determinants	**References**
Internal sustainability management practices (41 studies)	Schmidt et al. (2017), Severo et al. (2017), Adebanjo et al. (2016), Alzboun et al. (2016), Jabbour et al. (2016), Lu et al. (2016a, 2016b), Shin and Thai (2016), Alonso-Almeida et al. (2015), Dubey and Gunasekaran (2015), Chin et al. (2015), Hami et al. (2015), Masoumik et al. (2015), Soubihia et al. (2015), Lee et al. (2014) Thoo et al. (2014), Yu et al. (2014), Gotschol et al. (2014), De Giovanni and Vinzi (2014), Jabbour et al. (2014), Wong et al. (2014), Alonso-Almeida (2013), Grekova et al. (2013), Yang et al. (2013), De Giovani (2012), Gimenez et al. (2012), Green et al. (2012a, 2012b), Hollos et al. (2012), Jabbour et al. (2012), Kumar et al. (2012), Schoenherr (2012), Vinodh and Joy (2012), Wittstruck and Teuteberg (2011), Hrdlicka and Kruglianskas (2010), Pullman et al. (2009), Montabon et al (2007), Zhu and Sarkis (2007, 2004), Rao and Holt (2005), Kassinis and Soteriou (2003)
External sustainability management (e.g.collaboration) (32 studies)	Lu et al. (2016a, 2016b), Woo et al. (2016), Grekova et al. (2016), Dai et al. (2015), Agudo-Valiente et al. (2015), Hami et al. (2015), Blome et al. (2014), De Giovanni and Vinzi (2014), Mitra and Datta (2014), Yu et al. (2014), Gimenez and Sierra (2013), Meacham et al. (2013),Youn et al. (2013), Yang et al. (2013), Wong (2013), Delgado-Ceballos et al. (2012), De Giovani (2012), Gimenez et al. (2012), Green et al. (2012a), Hollos et al. (2012), Rasi et al. (2012), Kim et al. (2012), Lopez-Gamero et al. (2011a), Wittstruck and Teuteberg (2011), Yang et al. (2010), Vachon and Klassen (2008), Hussey and Eagan (2007), Zhu and Sarkis (2007, 2004), Rao and Holt (2005), Klassen and Vachon (2003)
Human Resources Management towards sustainability (22 studies)	Hussey and Eagan (2007), Dubey (2016), Chang (2016), Benn et al. (2015), Carballo-Penela and Castroman-Diz (2015),Wagner (2015), Chen et al. (2014), Jabbour et al. (2013), Longoni et al. (2014), Youn et al. (2013), Paille and Boiral (2013), Jayashree et al. (2013), Parisi (2013), Cantor et al (2012), Chen (2011), Lopez-Gamero et al. (2011b, 2010), Ronnenberg et al. (2011), Pagell and Gobeli (2009), Wu et al.(2008), Hussey and Eagan (2007), Daily (2012)
Pressure (15 studies)	Adebanjo et al. (2016), Dubey (2016), Böttcher and Müller (2015), Dubey and Gunasekaran (2015), Wagner (2015), Perramon (2014), Yu and Choi (2014), Agan et al.(2013), Ehrgott et al.(2013), Hsu et al. (2012), Reuter et al. (2012), Zailani et al. (2012b), Lopez-Gamero et al. (2011a, 2010), Ehrgott et al. (2011)
Social responsibility/ CSR (8 studies)	Glavas (2016), Lee and Park (2016), Park et al. (2016), Hanzaee and Sadeghian (2014), Lekakos et al. (2014), Agan et al.(2013), Mellat-Parast (2013), Ali et al. (2010)

Table 4: Main mediators in sustainability-performance empirical research

Mediators	References
Internal sustainability management practices (16 studies)	Adebanjo et al. (2016), Ajamieh et al. (2016), Hsu et al. (2016), Kirchoff et al. (2016), Lu et al. (2016b), Green et al. (2015), Amann et al. (2014), Mas'od and Chin (2014), Nejati et al. (2014), Perramon et al. (2014), Hajmohammad and Vachon (2014), Jabbour et al. (2013), Youn et al. (2013), Choi et al. (2013), Choi and Zhang (2012), Lee (2012), Yang et al. (2010)
Commitment to sustainability (leadership and employees) (8 studies)	Dubey et al. (2016), Glavas (2016), Benn et al. (2015), Wang (2014), Mellat-Parast (2013), Paille and Boiral (2013), Robertson and Barling (2013), Chen (2011)
Environmental performance (8 studies)	Gopal and Thakkar (2016), Khaksar et al. (2016), Golini et al. (2014), Lin et al. (2014), Sambasivan et al. (2013), De Giovani (2012), Green et al. (2012), Pullman et al. (2009)
External Sustainability Management (e.g. SC Collaboration) (7 studies)	Graham and Potter (2015), Luzzini et al. (2015), Chen and Hung (2014), Yang et al. (2013), Wittstruck and Teuteberg (2012), Zhu et al. (2012), Paulraj (2011)
Green innovation (7 studies)	Severo et al. (2017), Ryszko (2016), Hami et al. (2015), Lin et al. (2014), Wang (2014), Grekova et al. (2013), Wong (2013)

Table 5: Moderators in sustainability-performance empirical research

Moderators	References
Pressure	Huang and Yang (2014), Zhu and Sarkis (2007)
Green purchasing	Clark et al. (2014)
Strategic purchasing	Paulraj (2011)
Behaviors	Glavas (2016)
Enviropreneurship	Thoo et al. (2014)
Stakeholders influence	Hall and Wagner (2012)
Environmental collaboration	Chin et al. (2015)
Stages of EMS implementation	Wu et al. (2008)
Types of technologies deployed to address environmental issues	Sambasivan et al. (2013)
Firm's experience in other manufacturing systems	Wu et al. (2008)
Size	Agan et al. (2013)
Quality management (QM) programs	Zhu and Sarkis (2004)
Just-in-time (JIT) practice	Zhu and Sarkis (2004)
Utilitarian information systems factors	Lekakos et al. (2014)
Green advertising	Wong et al. (2014)

Table 6: Main performance indicators in sustainability-performance empirical research

Performance	References
Environmental Performance (51 studies)	Adebanjo et al. (2016), Jabbour et al. (2016), Khaksar et al. (2016), Kirchoff et al. (2016), Pipatprapa et al. (2016), Woo et al. (2016), Benitez-Amado et al. (2015), Benn et al. (2015), Boiral et al. (2015), Graham and Potter (2015), Green et al. (2015), Hami et al. (2015), Jabbour et al. (2015), Masoumik et al. (2015), Rae et al. (2015), Soubihia et al. (2015), Severo et al. (2015), Wagner (2015), Bhadauria et al. (2014), Chen et al. (2014),De Giovanni and Vinzi (2014), Huang and Yang (2014), Roy and Goll (2014), Gimenez and Sierra (2013), Kuei et al. (2013), Meachan et al. (2013), Sambasivan et al. (2013), Yang et al. (2013), Youn et al. (2013), Wong (2013), Daily et al. (2012), Green et al. (2012a, 2012b), Kim et al. (2012), Kumar et al. (2012), Lee (2012), Choi and Zhang (2011), Hall and Wagner (2012), Hong et al. (2012), Zailani et al. (2012b), Zhu et al. (2012), Chiou et al. (2011), Lopez-Gamero et al. (2011b), Ronnenberg et al. (2011), Huang and Shih (2010), Hwang et al. (2010), Pullman et al. (2009), Vachon and Klassen (2008), Zhu and Sarkis (2007), Hussey and Eagan (2007), Zhu and Sarkis (2004)
Financial Performance (30 studies)	Severo et al. (2017), Gopal and Thakkar (2016), Woo et al. (2016), Alonso-Almeida et al. (2015), Hami et al. (2015), Tomsic et al. (2015), Walker and Mercado (2015), Wagner (2015), Bhadauria et al. (2014), De Giovanni and Vinzi (2014), Gotschol et al. (2014), Huang and Yang (2014), Lu et al. (2014), Mitra and Datta (2014), Hajmohammad and Vachon (2013), Sambasivan et al. (2013), Thornton et al. (2013), Wong (2013) , Green et al. (2012a, 2012b), Hall and Wagner (2012), Zhu et al. (2012), Choi and Zhang (2011), Lopez-Gamero et al. (2011b, 2010), Huang and Shih (2010), Chang and Kuo (2008), Zhu and Sarkis (2007), Rao and Holt (2005), Zhu and Sarkis (2004)
Firm Performance (29 studies)	Schmidt et al. (2017), Ainin et al. (2016), Ajamieh et al. (2016), Fonseca and Ferro (2016), Grekova et al. (2016), Khaksar et al. (2016), Ryszko (2016), Benitez-Amado et al. (2015), Jorge et al. (2015), Masoumik et al. (2015), Cheng et al. (2014), Lin et al. (2014), Mitra and Datta (2014), Nejati et al. (2014), Perramon et la. (2014), Wang (2014), Agan et al. (2013), Bagur-Femeneas et al. (2013), Benitez-Amado et al. (2013), Grekova et al. (2013), Kuei et al. (2013), Yang et al. (2013), Youn et al. (2013), Green et al. (2012b), Benitez-Amado and Walczuch (2012), Hong et al. (2012), Zeng (2010), Montabon et al. (2007), Montabon et al. (2000)
Sustainability performance (22 studies)	Gelhard and Von Delft (2016), Lu et al. (2016a), Lu et. al. (2016b), Yusoff et al. (2016), Chin (2015), Heravi et al. (2015), Luzzini et al. (2015), Mohamed Radzi et al. (2015), Ye et al. (2015), Blome et al. (2014), Golini et al. (2014), Guanapathy et al. (2014), Longoni et al. (2014), Thoo et al. (2014), Jayashree et al. (2013), Parisi (2013), De Giovani (2012), Foerstl et al. (2012), Gimenez et al. (2012), Zailani et al. (2012a) Paulraj (2011), Pagell and Gobeli (2009)
Operational Performance (19 studies)	Adebanjo et al. (2016), Jabbour et al. (2016), Szasz et al. (2016), Jabbour et al. (2015), Bhadauria et al. (2014), Yu et al. (2014), Jabbour et al. (2013), Melnyk et al. (2003), Mellat-Parast (2013), Sambasivan et al. (2013), Green et al. (2012b), Jabbour, et al. (2012), Schoenherr (2012), Wiengarten et al. (2012), Zailani et al. (2012a), Yang et al. (2010), Pullman et al. (2009), Vachon and Klassen (2008), Wu et al. (2008)

Only a few studies comprised moderators in their analyses so the list of moderators (Table 5) covered all variables found in the literature. The results for mediators (Table 4) showed that internal and external sustainability management practices also act as significant mediators in sustainability-performance causal model. This means that there are drivers (antecedents) that help or motivate firms to adopt sustainable practices such as *pressure* (Adebanjo et al., 2016), *top management support* (Youn et al., 2013) and *site competence* (Golini et al., 2014) for *internal sustainability management practices*. For *external sustainability management* some drivers found in the literature were: *environmental proactivity* (Graham and Potter, 2015), *commitment to sustainability* (Luzzini et al., 2015) and even *internal environmental practices* (Yang et al., 2013).

Environmental Performance appeared as a mediator but proved to be the most significant measure of performance in the literature chosen (see Table 6), with 51 studies, followed by *financial performance* (30 studies), *firm performance* (29 studies), *sustainability performance* (22 studies) and *operational performance* (19 studies). Other measures had less than six studies.

According to Yang et al. (2013, p.59), *environmental performance,* also known as *green performance*, "can be measured in terms of various indexes that assess the reduction of firms' environmental impacts in a number of categories, each measured by a separate item variable (…) These variables include the reduction in use of water, energy, non-renewable resources, toxic inputs, solid waste, soil contamination, waste water emissions, emissions to air, noise, smell emissions, landscape damage, and the risk of severe accidents".

Financial performance measures are typically related to return on investment and sales, and may also encompass economic outcomes, such as operational costs, which also appears in *operational performance*. *Operational performance* usually comprises cost, quality, flexibility and delivery dimensions. While some studies proposed *operational performance* as a single construct (e.g. Green et al. 2012b; Jabbour et al., 2012; Jabbour et al. 2013), others tested some of these practices separately (e.g. Vachon and Klassen, 2008; Yang et al, 2010; Schoenherr, 2012; Wiengarten et al., 2012; Yu et al., 2014). Both ways are recorded in this construct in Table 6.

Firm performance is a construct that may comprises multiple factors, such as financial, market and operational performance. Green et al. (2012b, p.293), for instance, used the follows Green and Inman's (2005) definition of *firm performance*: "financial and marketing performance of the organization as compared to the industry average (Green and Inman, 2005). Performance measures proposed under the terms of *competitiveness* and of *business performance* were regrouped under *firm performance*, in Table 6. According to Yang et al. (2013, p.59) "measurement of competitiveness should include as many business performance dimensions as possible to provide a holistic view of environment's effects on firms' economic performance".

Sustainability performance are usually related to the triple bottom line (environmental, social and economic performance), nevertheless studies that considered only environmental or social performances were also included in this construct, using these dimensions either separately or aggregately.

It is worth noting that, among all 186 papers reviewed, only 13 papers analyzed the causal model that this dissertation aims to study: the impact of sustainability management practices on firms` manufacturing operational performance. Table 7 outlines a synthesis of the impacts of this relationship, depicting in general an overall positive effect of sustainability on performance.

Table 7: Synthesis of empirical research that analyses the impact of sustainability on operational performance

Reference	**Predecessors**	**Performance**	**Findings**
Adebanjo et al. (2016)	(i)Sustainable Management practices (ii)External Pressure	(i)Environmental (ii)Cost	The study has shown that external pressure has a significant direct and positive relationship with environmental outcomes. However, external pressure does not have a significant relationship with manufacturing performance. With respect to the mediating effect of sustainable management, the study finds sustainable management can mediate positively between external pressure and environmental outcomes but does not mediate between external pressure and manufacturing performance.
Green et al. (2012b)	Green Supply Chain Management (GSCM) practices	(i) Environmental (ii)Economic (iii)Operational (iv)Organizational	The adoption of GSCM practices by manufacturing organizations leads to improved environmental performance and economic performance, which, in turn, positively affect operational performance. Operational performance (single construct) enhances organizational performance. Operational performance reflects the organization's ability to satisfy customers in terms of on time delivery of quality products and the ability to do so more efficiently through reduced inventory and scrap levels.
Jabbour et al. (2012)	Environmental management practices	Operational	The main results indicate that the adoption of environmental management practices relates positively with the operational performance, measured as one construct that englobes cost, time to market, new products, quality, flexibility and delivery.
Jabbour et al. (2013)	Environmental Management practices	Operational	Environmental management tends to positively influence operational performance, measured as one construct that englobes cost, time to market, new products, quality, flexibility and delivery, but with a weak explanatory power. This finding indicates that relationship must be strengthened within the companies studied to generate synergy between environmental management and performance, creating win/win conditions.
Jabbour et al. (2016)	Green operational practices (GOPs)	(i)Operational (ii)Environmental	The main results show that (a) the proposed framework obtained an adequate statistical adjustment, (b) the internal barriers (IBs) are more significant than the external barriers (EBs) when adopting GOPs, (c) GOPs relate directly to the firms green and operational performance (OP), (d) the IBs also indirectly influence the firms green and OP and (e) the firm size does not significantly influence its green and OP.

Reference	**Predecessors**	**Performance**	**Findings**
Melnyk et al. (2003)	(i)Environmental management systems (EMS) (ii) ISO 14001 certification	(i)Cost (ii)Lead time (iii)Quality (iv)Marketplace (v) Reputation	The results strongly demonstrate that firms in possession of a formal EMS perceive positive impacts many dimensions of operations performance (cost, lead time and quality). The presence of the EMS promotes awareness and communication of environmental activities. ISO 14001 certification forces the people involved to examine the various processes and not just the outputs of the firm. By focusing on these processes and ideally altering them, the firm gains real and long-term improvements not only in the decreased level of pollution generated but also by increasing operations performance.
Pullman et al. (2009)	Environmental and Social Practices	(i)Environmental (ii)Quality (iii)Cost	Increased adoption of facility resource conservation and land management (environmental sustainability practices) improves environmental performance. Increased adoption of social sustainability practices improves quality performance. Quality performance improves with environmental performance. Cost performance improves with quality performance.
Schoenherr (2012)	Environmental initiatives	(i)Cost (ii)Quality (iii)Delivery (iv)Flexibility	The finding is indicative of the environmental initiatives of ISO14000 certification, pollution prevention and waste reduction have a positive influence on a plant's quality, delivery, flexibility, and cost performance. The initiative of recycling did not have any significant influence on performance. Plants in emerging economies will place greatest emphasis on the environmental initiatives compared to their counterparts in industrialized and developing regions of the world.
Vachon and Klassen (2008)	SC environmental collaboration	(i) Cost (ii)Quality (iii)Delivery (iv)Flexibility (v)Cycle time (vi)Setup time (vii) Environmental	The influence of collaboration in upstream and downstream was empirically assessed. The benefits of collaborative green practices with suppliers were broadest. Although environmental collaboration was not significantly linked with cost performance, collaboration was positively linked with quality, delivery and flexibility performance as well as with environmental performance.
Wiengarten et al. (2012)	Sustainability (environmental and social) investments	(i)Cost (ii)Delivery (iii)Quality (iv)Flexibility	Investments on sustainability practices (pollution prevention, recycling of materials, waste reduction and health/safety) significantly improve a plant's operational performance in terms of cost, quality and flexibility, in static industries. However, in dynamic industries the results show no significant improvement on the four dimensions of operational performance.

Reference	Predecessors	Performance	Findings
Yang et al. (2010)	(i)continuous improvement (ii)Supplier management (iii) Environmental management programs	(i)Cost (ii) Delivery (iii)Quality	Supplier Management (which includes selection, evaluation and collaboration) and Continuous Improvement (such as TQM and JIT) display positive effects on the cost and delivery competitiveness. Environmental management (EM) works as mediator and enhanced competitive advantages on cost and delivery. The insignificant relationship between EM programs and quality can be explained by the possibility that, in high tech industry, such electronics, some of the green activities might have impaired quality performance in the short term, as it is extremely rigid and sensitive to even very minor changes of materials and production environment.
Yu et al. (2014)	Internal and External Green Supply Chain Management (GSCM)	(i)Cost (ii)Flexibility (iii)Delivery (iv)Quality	Results show that internal Green Supply Chain Management (GSCM) - such as cross-functional cooperation for environmental improvements, EMSs and certification and environmental reports for internal evaluation - and GSCM with suppliers and customers are significantly and positively associated with flexibility, delivery, quality and cost.
Zailani et al. (2012a)	Environmental Purchasing and Sustainable packing	(i)Environmental; (ii)Social (iii)Economic (iv)Operational Performance	The study found environmental purchasing has a positive effect on three categories of outcomes (economic, social and operational), whereas sustainable packaging has a positive effect on environmental, economic and social outcomes.

2.2
Sustainability from an OM perspective

The Brundtland Commission defined sustainability as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 16). In 1992, the United Nations Conference on Environment and Development (UNCED) issued a declaration of principles stating that the protection of the environment and social and economic development are fundamental to sustainable development. Elkington (1998) called it the triple bottom line, advocating equal efforts devoted to economic, social and environmental sustainability (Gimenez et al. 2012; Yu et al., 2014; Najul et al., 2016). The Johannesburg Declaration reinforced the economic, social and environmental pillars of sustainability ten years later (WSSD, 2002).

Golini et al. (2014, p.448) defined the three pillars of sustainability as follows:

(i) Economic dimension of sustainability is defined as having the ability to generate enough cash flow to ensure liquidity and produce a persistent return for the long term (Vachon and Mao, 2008; Steurer and Konrad, 2009);

(ii) Environmental sustainability is obtained if a company consumes natural resources at as lower pace than the natural regeneration and generates limited emissions and waste (Vachon and Mao, 2008); and

(iii) Social sustainability is obtained when the organization actively supports the preservation and creation of skills as well as the capabilities of current and future generations, and promotes health and supports equal and democratic treatments within and outside its borders (McKenzie, 2004).

Buil et al. (2016, p.4) define sustainability as “the transformation of an organization’s management model towards the achievement of economic goals in a socially and environmentally responsible manner”.

According to Gunasekaran and Spalanzani (2012, p.36) “sustainability concepts should be considered as operations strategies similar to agile manufacturing, lean production and business process reengineering. This will help not only enhance the financial performance of an organization, but also satisfy social and environmental objectives and regulations.”

Bringing sustainability to OM field, Keindorfer et al. (2005, p. 489) defined Sustainable OM as “the set of skills and concepts that allow a company to structure and manage its business processes to obtain competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders and with due regard for the impact of its operations on people and the environment.”

The growing concern about environmental and social impact of manufacturing operations has given rise to a series of sustainable practices in manufacturing industries, both internally and in the supply chain. Consistent with Hami et al. (2015) sustainable manufacturing practices (SMP) is defined in this study as internal and external organizational practices that integrate environmental and social aspects into operational activities. SMP can permeate the entire product life cycle (Golini et al., 2014), in each of these operations activities:

(i) Product/Process design and development (Thomé et al., 2016);

(ii) Production (Baldwin et al., 2005);

(iii) Procurement (Vachon and Mao, 2006, 2008);

(iv) Supply chain distribution (Sarkis, 2003); and

(v) Recycling, remanufacturing and reverse logistics (Gunasekaran and Spalanzani, 2012).

Accordingly, this dissertation’s causal model will address internal and external sustainability management practices, encompassing both environmental and social dimensions into operations activities.

2.2.1 Theoretical basis

The two theoretical anchors employed in this research were the theory of the resource-based view of the firm (RBV) (Barney, 1991) and its extension, the natural resource-based view of the firm (NRBV) (Hart, 1995). The first theory posits that a firm, through a set of valuable, rare, inimitable and non- substitutable resources (the ‘‘VRIN’’ characteristics) can develop capabilities that provide sustainable competitive advantage (Schoenherr, 2012); and the second theory proposes that proactive environmental efforts may lead to sources of competitive advantage

(Graham and Potter, 2015). Firm resources can be related to physical, human and organizational capital resources (Barney, 1991). However, this study focus only on organizational capital resources by analyzing internal and external sustainability practices.

Building on the assumptions that strategic resources are heterogeneously distributed across firms and that these differences are stable over time, RBV examines the positive link between firm resources and sustained competitive advantage (Barney, 1991). According to Barney (1991. p.5) "a firm is said to have a sustained competitive advantage when it is implementing a value creating strategy not simultaneously being implemented by any current or potential competitors and when these other firms are unable to duplicate the benefits of this strategy."

The framework borrowed from Barney (1991), presented in Figure 5, suggests the conditions under which sustainability practices, for instance, can be a source of sustained competitive advantage. They are "valuable if they help improve a firm's effectiveness and efficiency, they are rare if they can provide competitive disparity beneficial to the firm, they are inimitable if they are difficult to replicate by other firms due to, for example, their uniqueness or complexity, and they can be called non-substitutable if there are no strategically equivalent resources" (Schoenherr, 2012, p. 118),

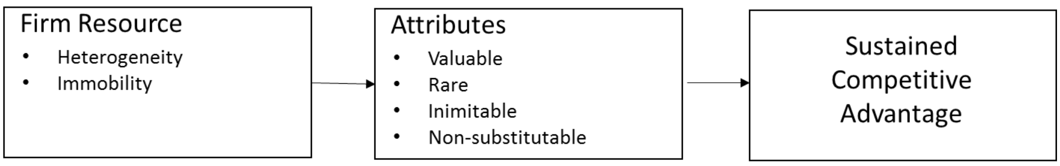

Figure 5: Barney's (1991) framework: relationship between resources and sustained competitive advantage

The NRBV is of particular interest to this dissertation. It introduces the element of environment management as being responsible for developing capabilities with "VRIN" characteristics that may yield cost advantages, as well as improve flexibility and delivery (Hart, 1995; Klassen and Whybark, 1999; Vachon and Klassen, 2008). In addition, NRBV offers a theoretical lens to understand the potential impact of environmental collaboration (external sustainability practice) in the performance of the supply chain.

In its original form, the NRBV focused on three broad groupings of practices: pollution prevention, product stewardship and sustainable development (Hart, 1995; Bhadauria et al., 2014; Graham ad Potter, 2015). Pollution prevention, or minimizing emissions, effluents and waste (Pullman et al., 2009), represents environmental efforts within internal operations and is captured in this study under the construct of internal sustainability management practices. Stewardship, or minimizing the costs of product life-cycle (Pullman et al., 2009), is the term used to capture efforts beyond the organizational boundaries, by working alongside other stakeholders in the supply chain (Vachon and Klassen, 2008; Wong et al., 2012). It can be done by setting standards and monitoring them and by developing collaborative relationships with supply chain partners and actively engage in joint problem solving activities (Vachon and Klassen, 2008; Graham and Potter, 2015). Collaboration practices will be captured in this dissertation as external sustainability management. The third element, sustainable development involves a broader range of external stakeholders such as competitors or governments (Graham and Potter, 2015) who are not directly involved in the production process and is therefore beyond the realm of this study.

These two complementary theories have been used consistently by researchers in operations, productions and supply chain management (Schoenherr, 2012). Furthermore, the number of studies analyzing the impact of the development of capacities and resources to understand the relationships between sustainability and operational performance is growing. Graham and Potter (2015) provides support for the propositions of the NBRV by finding positive link with environmental proactivity, environmental practices (pollution prevention and process stewardship) and cost performance. Pullman et al. (2009) found that building employee skills, capabilities and satisfaction, with implementation of social practices, lead to improved quality performance and through such quality improvements, overall costs are reduced. Schoenherr (2012) findings revealed that ISO 14000 certification, pollution prevention and waste reduction, representing VRIN resources for the firm, have positive effect on quality, delivery, flexibility and cost. Bhadauria et al. (2014) posit that green information system can be a resource for an organization to become more efficient and effective, leading to an improvement in operational performance.

2.3 Research model and hypotheses

This section presents the conceptual background to define individual constructs and their relationship in order to formulate the hypotheses that answer the third research question (How sustainability practices impact manufacturing operational performance?).

Following the framework developed by Kleindorfer et al. (2005) and consistent with the NRBV of the firm, this dissertation classified sustainability management practices as internal and external. The effect of internal practices will be analyzed on the one hand and the impact of practices that improve suppliers' sustainability will be analyzed on the other hand. Based on Gimenez et al. (2012), sustainability management practices took into account both environmental and social dimensions.

The operational manufacturing performance will be evaluated in four primary competitive capabilities of cost, quality, flexibility and delivery, commonly encountered in similar studies (Vachon and Klassen, 2008; Schoenherr, 2012; Wiengarten et al., 2012; Yu et al., 2014).

2.3.1 Internal sustainability management practices construct

Borrowing from De Giovanni (2012), internal sustainability management practices is defined in this dissertation as a set of activities aiming at achieving internal targets defined by managers, CEO or imposed by legislation. It includes practices such as ISO 14000 certification (Kitazawa and Sarkis, 2000; Yu et al., 2014), pollution prevention (Klassen and Whybark, 1999; Graham and Potter, 2015), recycling and reuse of material (Wiengarten et al., 2012), waste reduction (Schoenherr, 2012), energy and water consumption reduction programs (Sarkis, 1998), formal sustainability oriented communication, training programs and involvement (Daily and Huang, 2001), eco-design (Lee et al., 2014), green purchasing (Chen et al., 2010) and cross-functional cooperation for environmental improvement (Yu et al., 2014). Internal social practices are equally part of internal sustainability management and may include social certifications (e.g. SA8000 or

OHSAS 18000) (Longo et al. 2005), health and safety (Wiengarten et al., 2012), and work/life balance policies (Longo et al. 2005).

2.3.2 External sustainability management construct

External sustainability management reflects the attitude to implement sustainable practices collaboratively (Vachon and Klassen, 2008; De Giovanni, 2012). It includes training suppliers and joining efforts with them to ensure that the materials and equipment supplied are produced through environmental and social friendly processes (Krause et al., 2000; Rao and Holt, 2005; Yu et al., 2014).

Although collaboration in the supply chain includes both suppliers and customers, in this study the external sustainability management will be represented only by suppliers collaboration because its effect on performance is amply documented in the literature. According to Chin et al. (2015, p. 696) environmental collaboration with suppliers includes “cooperation to achieve environmental objectives and improve waste reduction initiatives, providing suppliers with design specification that include environmental requirements for purchased items, encouraging suppliers to develop new source reduction strategies, working with suppliers for cleaner production and helping suppliers to provide materials, equipment, parts and services that support organizational goals”. In regard to the social aspect of sustainability, variables for appraisal should include security, safety, and neighboring relationships (Lu et al., 2016).

2.3.3 Manufacturing operational performance constructs

Yu et al. (2014) refers operational performance to the strategic dimensions by which a company chooses to compete. There is a general agreement in the OM literature that cost, quality, flexibility and delivery are the core and most often mentioned competitive operational capabilities (Hayes and Wheelwright, 1984; Vachon and Klassen, 2008; Rosenzweig and Easton, 2010; Schoenherr, 2012; Jabbour et al., 2013, Wiengarten et al., 2012; Yu et al., 2014).

Although many studies analyses operational performance dimensions separately, operational performance can also be found as a single construct (e.g.

Green et al., 2012b) or aggregated in second order constructs, such as efficiency (cost and lead time) and effectiveness (quality, flexibility and delivery) (e.g. Szasz et al., 2016). Regrouping dimensions may provide more parsimonious models, with fewer dependent variables, but may also restrict the analysis of the results.

To assist the disentanglement of the differential effects of internal and external sustainability management practices on operational manufacturing performance, the author decided to compute separately the four primary operational dimensions: cost, quality, flexibility and delivery (Schoenherr, 2012). This measurement is consistent with Ketokivi and Schroeder's (2004) acknowledging that manufacturing operational performance lays in a multi-dimensional space and the measures might not correlate. For example, the determinants of quality may be different from those of delivery, hence, a regression (or equivalent) model that combines the two dependent variables into one is likely to be mis-specified (Ketokivi and Schroeder, 2004).

Borrowing from Jabbour et al. (2013), Table 8 provides definitions for the operational performance variables of this study.

Table 8: Operational performance dimensions and definitions

Dimensions	**Definitions**	**References**
COST	Seeks the lowest price compared to competitors, the lowest total production cost, or the highest production capacity.	Hayes and Wheelwright (1984), González-Benito (2005), González-Benito (2006)
QUALITY	Zero-defect manufacturing or manufacturing of durable products.	Hayes and Wheelwright (1984), González-Benito (2005), González-Benito (2006)
FLEXIBILITY	Quick changes in product design, quick introduction of new products, quick changes in production volume, broad variety of products, or quick changes in product mix.	Hayes and Wheelwright (1984), González-Benito (2005), González-Benito (2006)
DELIVERY	Quick delivery or reliability in timely deliveries.	Hayes and Wheelwright (1984), González-Benito (2005), González-Benito (2006)

Source: Jabbour et al. (2013, p.131)

2.3.4
Internal sustainability management practices and manufacturing performance relationship

The pressure exerted over companies to become more environmentally and socially responsible is evidenced in several studies (e.g. Vachon and Klassen, 2008; Pagell and Gobelli, 2009; Wiengarten et al., 2012; Schoenherr, 2012; Bhadauria et al., 2014; Yu et al., 2014; Yu and Choi, 2014; Adebanjo et al., 2016). However, the adoption of sustainable practices is not obvious as they are costly and complex to implement, involving human resources and processes changes. There is a growing concern among practitioners and academics if responses to social and environmental issues contribute to profits and, ultimately, to competitive advantages. The ongoing debates are often framed around the question of ‘‘does it pay to be green/sustainable?’’ (Pagell and Gobeli, 2009).

RBV of the firm argues that companies are a bundle of strategic and operating resources, and that taking in unique, valuable, non-substitutable and inimitable resources can become a source of competitiveness. Therefore, in that sense, if sustainable practices have these attributes, as shown in Section 2.1.1, they are able to provide firms with advantages at each stage of the supply chain (Yang et al, 2013).

Positive links between internal sustainability management practices and overall performance of the firm have been established in the literature (e.g. Rao and Holt, 2005; Green et al., 2012a; Schoenherr, 2012; Yang et al., 2013; Bhadauria et al., 2014). However, only a few have analyzed the impact of both environmental and social sustainability taken together (e.g. Pullman et al., 2009; Pagell and Gobeli, 2009; Gimenez et al., 2012; Hami et al., 2015; Adebanjo et al., 2016). Yet, environmental management is still the primary concern among researchers. In empirical sustainability research, as shown in Chapter 2 (Table 7), there are also a limited number of studies on manufacturing operational performance at the plant level.

Pullman et al. (2009) studied the impact of environmental and social internal programs on environmental, quality and cost performance in the US food industries. Results indicate that environmental performance improvements lead to improved quality, which in turn improves cost performance. Adebanjo et al. (2016), however, showed no relationship between internal sustainability programs, which included environmental and social aspects, and cost efficiency. Pagell and Gobeli's (2009) findings suggest that employee well-being (a measure of social sustainability internal practices) and environmental sustainability internal practices affect operational performance. According to Carters and Rogers (2008), health and safety concerns and better work conditions (measures of social sustainability internal practices) can increase motivation and productivity, lower recruitment and labor turnover costs, and reduce the absenteeism of supply chain personnel leading to lower labor costs. Wiengarten et al. (2012) show that environmental investments in static industries does pay off in terms of cost, quality and flexibility.

"One of the core arguments underpinning the proposition that it pays to be green is the idea of eco-efficiency (Sharma and Henriques, 2005), which is founded on the premise that reductions in environmental impacts are reductions in wasted resources and hence behaviors that reduce environmental waste will simultaneously improve operational efficiency" (Wiengarten et al., 2012, p. 543). These waste-related practices involve innovations that lower the total cost of a product or improve its value, thus offsetting the costs of improving environmental impact as suggested by Porter and Van Der Linde (1995). Gimenez et al. (2012) called attention that not only reduction of waste but also the use of more environmentally friendly materials and process can lead to resource reduction and manufacturing efficiency, and consequently cost savings.

Cruz and Wakolbinger (2008) pointed out that the short term costs to implement sustainable practices would be less compared to the long term costs of liability for pollution, compliance with regulation, dangerous operations, use of hazardous raw materials, production of hazardous waste, and health and safety issues.

Melnyk et al. (2003), Schoenherr (2012), and Yu et al. (2014) have found that internal practices of environmental sustainability, such as environment management systems and certifications, play an important role in improving the operational performance of cost, quality, delivery and flexibility. Implementing such practices involves root-cause analyses, data tracking efforts, and structured reporting and information evaluation systems analogous to Total Quality Management (TQM) used to enhance quality, so they can potentially decrease production inefficiencies, and may result in a shift in management orientation toward operational performance (Pil and Rothenberg, 2003).

Accordingly, we put forward the following hypotheses relating internal sustainability management practices to manufacturing operational performance.

H1a: Implementation of internal sustainability management practices lead to higher levels of manufacturing cost efficiency.

H1b: Implementation of internal sustainability management practices lead to higher levels of quality.

H1c: Implementation of internal sustainability management practices lead to higher levels of flexibility.

H1d: Implementation of internal sustainability management practices lead to higher levels of delivery.

2.3.5
External sustainability management and manufacturing performance relationship

The application of sustainability to the supply chain only emerged in the end of the 1980s, but since then this topic has become increasingly popular in manufacturing supply chains (Sarkis, 2001, 2006; Olugu et al., 2010; Yang et al., 2010). In the new order economy, it is important not only to enhance profits, but effectively design and manage logistics resources within the supply chain in order to mitigate negative environmental and social impacts. Besides, leading firms need to ensure that the components and materials used in their production process meet stringent environmental and social requirements, as firms are being held increasingly accountable for supplier`s irresponsible behavior (Rao and Holt, 2005; Graham and Porter, 2015). Sustainability principles should, then, be taken into consideration in the upstream supply chain, which involves make or buy decisions, supplier selection, purchasing, procurement and outsourcing activities (Golini et al., 2014). Thus, the involvement and support of suppliers are crucial to achieving potential benefits from implementing sustainability practices.

Supplier environmental collaboration represents the input stage of the process stewardship approach, in the NRBV theory. Suppliers normally commit to collaborative arrangements because they perceive potential gains such as, risk sharing, access to complementary resources, reduced transaction costs and improved competitive advantage (Cao and Zhang, 2011; Graham and Porter, 2015). Several studies have indicated the importance of supplier partnership for sustainability management and overall performance. Green et al. (2012a) found that environmental collaboration and monitoring practices among supply chain partners lead to improved environmental and organizational performance. Pagell et al. (2010) findings suggest that the ability to form collaborative relationships with suppliers in order to improve sustainability is a valuable asset that results in sustainable advantage in making responsible and profitable supply chains. Yang et al. (2013) findings show that environmental performance and external green collaboration act as mediator variables between internal green practices and firm competitiveness, and they influence firm competitiveness positively. Gimenez et al. (2012) show that supply chain assessment alone is unlikely to be effective, while supplier collaboration contributes to improve the triple bottom line.

According to Vachon and Klassen (2008, p. 302) collaboration includes "knowledge integration and cooperation between organizations, which are recognized as resources that might generate competitive advantage (Grant, 1996). As such, manufacturing organizations adopting collaborative activities with their suppliers and customers can develop organizational skills and capabilities (Lorenzoni and Lipparini, 1999), which can be expected to translate not only into improved environmental performance, but also alleviate negative effects throughout the production process (Hart, 1997; Porter and van der Linde, 1995b)."

Although there is limited research focusing on operational manufacturing performance, findings usually indicate a positive link to this relationship. Walton et al. (1998) reinforces that organizations that integrate their supply chains reduce operating costs. Vachon and Klassen (2008) found that collaboration with suppliers on environmental issues contribute to improvement in quality, delivery and flexibility. Yu et al. (2014), by examining China's automotive industry, also found that green supply chain management integrated with suppliers were significantly and positively associated with quality, delivery, flexibility and cost. Yang et al. (2010) results suggest that firms with closer supplier partnerships and solid continuous improvement practices are more likely to develop a proactive environmental management program, which in turn enhances manufacturing competitive advantage through cost savings, delivery competitiveness and process/product innovation.

External sustainability management may lead to more efficient processes and further gains in terms of cost reductions (Graham and Potter, 2015). Therefore, the following hypotheses address the direct association between external sustainability management practices and operational manufacturing performance.

H2a: Implementation of external sustainability management lead to higher levels of manufacturing cost efficiency.

H2b: Implementation of external sustainability management lead to higher levels of quality.

H2c: Implementation of external sustainability management lead to higher levels of flexibility.

H2d: Implementation of external sustainability management lead to higher levels of delivery.

The research model depicted in Figure 6 summarizes the hypotheses. This framework is in line with the RBV and NRBV of the firm and is consistent with the findings from previous empirical research in sustainability management practices.

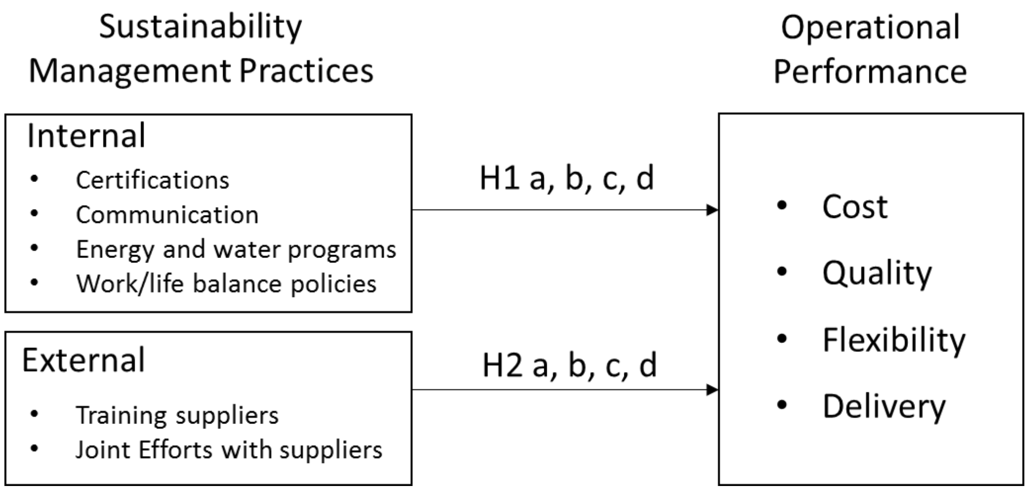

Figure 6: Research model and hypotheses

3
Methodology

This dissertation makes use of empirical research to analyze the relationship between sustainability management and manufacturing operational performance. Flynn et al. (1990) define empirical research in OM as referring to research that makes use of data derived from naturally occurring field-based observations, taken from industry. The survey method, chosen for data collection, is widely used in OM empirical research (Scudder, 1998).

Section 3.1 presents the survey used for data collection. Section 3.2 displays statistical techniques used to validate the measurement model and to test the hypotheses. Section 3.3 introduces the measures (consistent with the definitions and theoretical background described in Chapter 2) and the control variables used in data analysis.

3.1
Survey design and research sample

Data was collected from the sixth (2013-2014) round of the International Manufacturing Strategy Survey (IMSS-VI). The IMSS is a questionnaire based research project involving several countries. A group of twenty business schools led by the London Business School and Chalmers University of Technology (Sweden) originally launched this longitudinal project. The questionnaire was developed to study manufacturing management strategies and was applied in 1992, 1996, 2001, 2005, 2009 and 2013-2014. It has been improved during each round by an international group of researchers and it is currently led by the Politecnico di Milano and by the University of Bergamo, Italy (IMSS, 2017).

There are three sections in the questionnaire. The first section refers to the business unit, which includes the description of the unit, its competitive strategy, services offered and organization. The second section refers to the plant's dominant activity, including manufacturing process design and manufacturing performance. The last section also refers to the plant's dominant activity, but also includes current manufacturing and supply chain practices, past action programs, planning and control, technology, quality, environmental and social sustainability management, product development, risk management, supply chain, and manufacturing network. Although the structure of the questionnaire has remained the same over time, in each round, some questions are updated or removed, and new questions are added. Specific sustainability issues have been included in IMSS V (2009-2010) and VI (2013-2014) (IMSS, 2017).

The IMSS-VI sample consists of 931 manufacturing plants from 22 countries, with a 13% response rate (Sousa and da Silveira, 2017). The data selection was restricted to companies with the six International Standard Industrial Classification (ISIC rev.4) codes ranging from 25 to 30 (see Table 10), preferably with more than 50 employees. The IMSS-VI sample distribution in terms of countries and gross domestic product (GDP) can be found in Table 9 and in terms of ISIC code, size and job title of the respondent in Table 10.

The research is centrally coordinated to ensure consistency in data collection procedures across different countries. Analysis of non-respondent bias and late-respondent bias tests were performed and validated before the compilation of the dataset (Adebanjo et al., 2016). The companies are sampled randomly or by convenience. For random sampling, each country coordinator randomly selects and contacts the firms from a sampling frame previously established using national databases (Adebanjo et al., 2016). For convenience sampling, the selection is voluntarily biased upwards, with choices among the best practice companies within each country (best performing, financially stable and with more international visibility) (Golini et al., 2014).

Data from several IMSS rounds has been used in manufacturing strategy studies such as those carried out by Voss and Blackmon (1998), Frohlich and Westbrook (2001), Thomé et al. (2014a) and Szasz et al. (2016). Studies from Gimenez et al. (2012), Golini et al. (2014) and Longoni et al. (2014), among others, have used the IMSS database, focusing on the relationships between sustainability and performance.

Table 9: IMSS-VI distribution by country and GDP per capita

Country	N	%	GDP (US$)
Belgium	29	3%	46,961.16
Brazil	31	3%	11,900.29
Canada	30	3%	51,225.83
China	128	14%	7,289.57
Denmark	39	4%	60,846.33
Finland	34	4%	49,751.33
Germany	15	2%	46,683.89
Hungary	57	6%	13,803.67
India	91	10%	1,516.51
Italy	48	5%	35,273.63
Japan	82	9%	37,351.18
Malaysia	14	2%	11,140.36
Netherlands	49	5%	51,781.88
Norway	26	3%	100,170.07
Portugal	34	4%	21,871.55
Romania	40	4%	9,798.53
Slovenia	17	2%	23,573.00
Spain	29	3%	29,544.58
Sweden	32	3%	59,591.61
Switzerland	30	3%	85,140.07
Taiwan	28	3%	45,750.00
USA	48	5%	53,529.38
Total	931	100%	

Table 10: IMSS-VI distribution by ISIC code, size and job title

ISIC code	N	%
25 - fabricated metal products	282	30%
26 - computer, electronics and optical products	123	13%
27 - electrical equipment	153	16%
28 - machinery and unclassified equipment	231	25%
29 - motor vehicles, trailers and semi-trailers	93	10%
30 - other transport equipment	49	5%
Total	931	100%
Size (number of employees)		
Less than 250	409	44%
Between 250 and 499	151	16%
Between 500 and 999	119	13%
More than 999	250	27%
Total	929	100%
Job Title		
Manager	455	60%
Director	180	24%
Others	126	17%
Total	761	78%
Missing	170	22%

Respondents that did not provide the required information for the analysis (e.g., size) or that had missing data on any of the items used as dependent and independent variables were excluded. Thus, the resulting sample consisted of 674 manufacturing plants from all 22 countries. The distribution of the sample in terms of country, industry and size is shown in Figure 7.

Prior to the analysis, data was checked for errors and outliers, and assessed for skewness and kurtosis. Neither outliers nor departures from the assumptions of normality and homoscedasticity were detected.

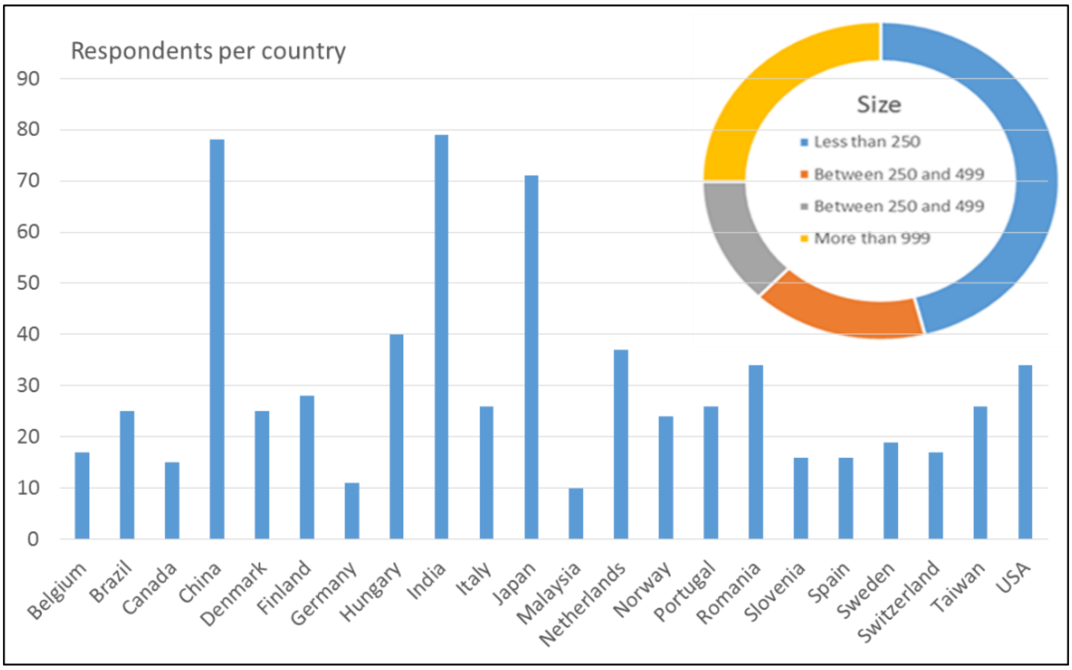

Figure 7: Sample profile

3.2
Multivariate techniques: SEM and Regression Analysis

Structural Equation Model (SEM) has become a popular multivariate approach to assess how theory fits reality as represented by data. The process begins with a good theoretical definition of the constructs involved. This is particularly important for SEM because it is useful for testing hypotheses and potentially confirming theory (Hair et al., 2010).

Hair et al. (2010b, p.4) says that “SEM is predicated on a strong theoretical model by which latent constructs are defined (measurement model) and these constructs are related to each other through a series of dependent relationships (structural model, also known as causal model). The emphasis on strong theoretical support for any proposed model underlies the confirmatory nature of most SEM applications".

The term structural equation modeling (SEM) does not designate a single statistical technique but instead refers to a family of related procedures. Other terms such as covariance structure analysis, covariance structure modeling, latent variable analysis, analysis of covariance structures or causal modeling are also used in the literature to classify these techniques together (Hair et al. 2010; Kline, 2011). SEM is essentially grounded, though, in two familiar multivariate techniques: factor analysis and multiple regression analysis (Hair et al. 2010).

Even though SEM has the advantage of simultaneously estimating the measurement model and the structural model, this study will follow Anderson and Gerbing's (1988) two-step approach for SEM. First, using Confirmatory Factor Analysis (CFA), the measurement model has to be developed and assessed by analyzing the goodness of fit (GOF) of the model and by testing the construct's validity. CFA in SEM can effectively asses the consistency of measurement among scale items and of pre-specified models with its associated network of theoretical concepts (Jöreskog, 1993). If the measurement model cannot be validated, researchers should refine the measures or even collect new data, if necessary. If and only if the refined model can be validated, the structural model test should then be proceeded (Hair et al., 2010).

Part of the process for the first step (measurement model) includes defining parameter estimators for SEM. Maximum Likelihood (ML) is the most widely used fitting function for structural equation models (Schermelleh-Engel et al., 2003) and, therefore, was chosen for this study. Nearly all major software programs, such as LISREL and AMOS (selected for this dissertation`s CFA analysis), use ML as the default estimator. Simulation studies suggest that, under ideal conditions, ML provides stable and valid results with samples as small as 50. Nevertheless, ML is sensitive to multivariate normality and other authors recommend larger sample sizes of at least N>200 (Hair et al. (2010a) or N>400 (Boomsma & Hoogland, 2001).

Another method frequently used for parameter estimation in SEM is the weighted least square (WLS) method (Hair et al. 2010), also known as the asymptotically distribution free (ADF) method (Browne, 1984). It was created as an alternative to ML because it can still be used "if some of the observed variables are ordinal and others continuous, if the distribution of the continuous variables deviate considerably from normality, or if models include dichotomous variables" (Schermelleh-Engel et al., 2003, p.27). However, some authors would say that ML performs better and should be preferred, as ML has proven quite robust to violations of normality assumptions. (Hu et al., 1992; Olsson et al., 2000; Hair et al., 2010).

The CFA begins with measurement model specification, which means the process to specify the indicators (also called *factors*, *manifest variables, measured variable* or *observed variables*) for each construct (also called *latent variable* or *unobserved variable*). The development of the measurement model must consider unidimensionality, that is: the set of indicators must be explained by only one construct. Additionally, to avoid misidentification, it is necessary to set the scale of the construct, in one of two ways: (i) fix one of the factor loadings (called *regression weight*, in AMOS) on each construct to a specific value (1 is typically used); or (ii) fix the value of the variance of the construct (again 1 makes a good value as it transforms the results into standardized form by having each element on the diagonal of the estimated covariance matrix among constructs equaling one) (Hair et al., 2010a). In this dissertation, the author decided to use the first method.

After specifying the measurement model, both the overall model fit and the criteria for construct validity must be examined. The assessment starts with analyzing the CFA output: goodness of fit (GOF) indexes, which indicate how well a specific model reproduces the observed covariance matrix.

The fundamental measure of differences between observed and estimated covariance matrices is the chi-square ($\chi 2$). The $\chi 2$ value increases as differences (residuals) are found when comparing the two matrices. Therefore, in SEM, the smaller the $\chi 2$, the better the theory fits reality.

Although the chi-square test is the most common method used to evaluate measurement models, it should not serve as the sole basis for judging a model fit, especially since it is sensitive to sample size (for large sample sizes the test is almost always significant, leading to p-values < 0.05) and also to violations of the multivariate normality assumption (Schermelleh-Engel et al., 2003; Marôco, 2014). There is a certain disagreement on which fit indexes should be considered and, therefore, multiple GOF indexes should be reported simultaneously in order to judge whether a model is consistent with the empirical data (Schermelleh-Engel et al., 2003; Hair et al., 2010a, Marôco, 2014).

Hair et al. (2010a) suggested relying on at least one absolute fit index and one incremental fit index, in addition to the $\chi 2$ results. An absolute fit statistic is the normed $\chi 2$, which is the chi-square value divided by the number of degrees of freedom (*df*). Generally, $\chi 2/ df$ indexes with values of 3.0 or less are associated with better fitting models. (Jöreskog and Sörbom, 1993; Hair et al., 2010a). Some authors, nevertheless, would accept less than 5.0 (Wheaton et al., 1977; Marôco, 2014), but will be considered poor fit.

Another absolute fit index is the RMSEA (Root Mean Square Error of Approximation). It is widely used, but according to Hair et al. (2010a) is best suited to large samples (N>500). RMSEA is a measure of approximate or close fit in the population, rather than exact fit, and is therefore concerned with the discrepancy due to approximation. The acceptable range of RMSEA for a 90% confidence interval is between 0.05 and 0.10, although less than 0.05 is preferred (Marôco, 2014), it is bounded below by zero. Hair et al. (2014) report that the acceptable RMSEA is between 0.03 and 0.08, with 95% confidence. The RMSEA confidence interval (CI) shows that, with a certain level of confidence, the given interval contains the true value of the fit index for that model in the population (MacCallum et al., 1996). PCLOSE (p-value for test of close fit- RMSEA) should be higher than 0.05 (Arbuckle, 2013; Marôco, 2014).

Incremental fit indexes could be the NFI (Normed Fit Index); the Nonnormed Fit Index (NNFI), also known as TLI (Tucker Lewis Index); and the CFI (Comparative Fit Index). These indexes values range from zero to one, with higher values indicating a better fit. NFI has an acceptable fit if its value is above 0.90, but 0.95 indicates a good fit in relation to the baseline. TLI and CFI indexes are usually associated with a model that fits well with values above 0.97, but above 0.95 is acceptable (Schermelleh-Engel et al., 2003). An advantage of TLI and CFI is that they are less affected by sample size (Schermelleh-Engel et al., 2003).

The mathematical expressions for the fit indexes chosen for this dissertation are provided in Appendix 1. Appendix 2 is the guideline for fit indexes provided by Hair et al. (2010a) offers different characteristics of GOF indexes for different model situations (e.g. different sample sizes and model complexity). Simpler models and smaller samples should be subject to more strict evaluation than more complex models with larger samples.

The next step in confirming the measurement model is construct validity, that includes: (i) convergent validity, which means that the indicators (factors) of a specific construct should converge or share high proportion of variance in common, and (ii) discriminant validity, that is the extent to which a construct is truly distinct from other constructs (Hair et al, 2010a).

CFA provides information to calculate indicators of convergent validity, such as composite reliability (CR) and average variance extracted (AVE), defined as:

$$CR = \frac{\left(\sum_{i=1}^{K} \lambda_i\right)^2}{\left(\sum_{i=1}^{K} \lambda_i\right)^2 + \sum_{i=1}^{K}(1-\lambda_i^2)} \qquad [1]$$

and

$$AVE = \frac{\sum_{i=1}^{K} {\lambda_i}^2}{\sum_{i=1}^{K} {\lambda_i}^2 + \sum_{i=1}^{K}(1-\lambda_i^2)} \qquad [2]$$

where:

$\boldsymbol{\lambda}$ is the standardized factor load (or regression weights, using AMOS terminology).

Convergent validity needs to meet all three criteria suggested by Fornell and Lacker (1981):

(i) λ of at least 0.5 and ideally of 0.7 or higher (Hair et al., 2010a);

(ii) CR above 0.6 and ideally 0.7 or higher (Hair et al., 2010a); and

(iii) AVE above 0.5 (Hair et al., 2010a).

Discriminant validity is supported when the AVE`s square root from a construct is greater than the shared variance between constructs (Fornell and Lacker, 1981; Hair et al., 2010a).

The observation that a particular theoretical model is appropriate to explain the relational structure of the data does not prove, however, that this model is unique. It only demonstrates that the theoretical framework is appropriate for the covariance matrix extracted from the data, not excluding other theoretical models that could be equally plausible. Anderson and Gerbing (1988, p.421) say that “models are never confirmed by data; rather, they gain support by failing to be disconfirmed. Although a given model has acceptable goodness of fit, other models that would have equal fit may exist, particularly when relatively few paths relating the constructs to one another have been specified as absent”. Therefore, models should be theory-driven.

After verifying that the measurement model is valid, the next step is to specify and test the structural model, which comprises theoretical hypotheses. In conformity with OM empirical research practices, hierarchical stepwise multiple regression will be used to test the structural model (for a similar approach combining factor analysis and multivariate regression analysis see Zhu and Sarkis, 2004; 2007; Da Silveira and Sousa, 2010; Yang et al., 2010; Delgado-Ceballos, 2012; Gimenez et al. 2012; Wiengarten et al., 2012; Golini et al., 2014; Longoni et al., 2014; Thomé et al., 2014a, 2014b; Thomé and Sousa, 2016). This method is appropriate since all measures related to performance and sustainable practices are averaged Likert scales that can be considered as interval variables, thus suitable for parametric tests (Carifio and Perla, 2007, 2008; Golini et al., 2013). Chapter 4 provides details of the regression method and results, as well as the development and assessment of the measurement model.

3.3
Measures

The measures for internal sustainability management practices (INT_SUST), external sustainability management (EXT_SUST), cost efficiency (COST), quality (QUA), flexibility (FLEX) and delivery (DEL) performances are in Table 11.

Table 11: Measurement Items

Constructs	IMSS-VI questions	N	μ	σ
INT_SUST Indicate the effort put in the last three years into implementing action programs related to: [1=None; 5=High]				
	Environmental certifications (e.g. EMAS or ISO 14001)	674	3.25	1.40
	Social certifications (e.g. SA8000 or OHSAS 18000)	674	2.65	1.47
	Formal sustainability oriented communication, training programs and involvement	674	2.92	1.19
	Energy and water consumption reduction programs	674	3.12	1.16
	Pollution emission reduction and waste recycling programs *	674	3.14	1.19
	Formal occupational health and safety management system *	674	3.40	1.10
	Work/life balance policies	674	2.79	1.15
EXT_SUST Indicate the effort put in the last three years into implementing action programs related to: [1=None; 5=High]				
	Training/education in sustainability issues for suppliers' personnel	674	2.49	1.23
	Joint efforts with suppliers to improve their sustainability performance	674	2.74	1.17
Operational manufacturing performance How does your current performance compare with your main competitor(s)? [1 = Much lower; 5 = Much higher]				
COST	Unit Manufacturing Costs	674	3.02	0.77
	Ordering Costs	674	3.04	0.67
QUA	Conformance quality	674	3.51	0.76
	Product quality and reliability	674	3.66	0.78
FLEX	Volume flexibility	674	3.45	0.79
	Mix flexibility	674	3.43	0.79
DEL	Delivery speed	674	3.55	0.83
	Delivery reliability	674	3.59	0.84

(*) Excluded in subsequent validation stages
Note: All items measured on a five-point scale with degree of adoption end points 1=Much worse and 5=Much better

Survey items were selected based on theory (content validity for similar constructs in the literature) and some were subsequently dropped due to statistical reasons. The author kept in the model exclusively items contributing to the increase of overall model goodness of fit.

3.3.1
Sustainability management practices

Internal and external sustainability management practices are both measured on a five-point item scale response format indicating the effort exerted by the company during the last three years (1= none; 5= high). The sustainability management practices included in this study are in accordance with similar constructs in the literature and the items available (manifest variables) in the IMSS-VI database.

The internal sustainability management included: (i) environmental certifications (Kitazawa and Sarkis, 2000); (ii) social certifications (Longo et al., 2005); (iii) formal sustainability oriented communication, training programs and involvement (Daily and Huang, 2001); (iv) energy and water consumption reduction programs (Sarkis, 1998); (v) pollution emission reduction and waste recycling programs (Klassen and Whybark, 1999); (vi) formal occupational health and safety management system (Longo et al., 2005); and (vii) work/life balance policies (Longo et al., 2005).

External sustainability management practices included: (i) training/education in sustainability for suppliers' personnel (Krause et al., 2000); and (ii) joint efforts with suppliers to improve their sustainability performance (Krause et al., 2000). In this case, there are no distinctions between social and environmental practices because when firms collaborate with each other to improve sustainability, they use the same practices to work on both types of issues (environmental and social).

The author decided not to consider suppliers' sustainability performance assessment in external practices for several reasons. In the empirical research analysis of Chapter 2, the supply chain collaboration proved to be more relevant than assessment. Moreover, Klassen and Vachon (2003) and Gimenez et al. (2012) explored both dimensions of supply chain activities— collaboration and assessment— but only collaboration proved to be effective. Additionally, De Giovanni (2012) affirms that the purpose of external environmental management is to collaborate with suppliers in order to make the supply chain more sustainable.

3.3.2 Operational manufacturing performance

Operational manufacturing performance will be measured with cost, quality, flexibility and delivery dimensions (constructs), through eight measured variables (indicators) selected in IMSS-VI. Table 12 shows literature classification for all manifest variables of operational manufacturing performance.

Table 12: Indicators and literature classification for operational manufacturing performance

Dimensions	Measured variables	Literature Classification
Cost	Unit manufacturing cost	Ferdows and De Meyer (1990)
	Ordering cost	Woo et al. (2001)
Quality	Conformance quality	Sitkin et al. (1994)
	Product quality and reliability	Kimura et al. (2007)
Flexibility	Volume flexibility	Jack and Raturi (2002)
	Mix flexibility	Hallgren and Olhager (2009)
Delivery	Delivery speed	Lode and Lee (1994)
	Delivery reliability	Ahmad and Dhafr (2002)

Da Silveira and Sousa (2010), Thomé et al. (2014a, 2014b), Szasz el at. (2016), among others, also applied these dimensions to the IMSS dataset. They are measured on a five-point Likert scale with endpoints 1= much worse and 5= much better, in answering the following question: “How does your current performance compare with your main competitor(s)?” The use of a different timeframe (i.e., “effort in the last three years” versus “current performance”), posits that the impact of sustainability management practices on operational manufacturing performance may be differed over time and effects will be perceived after a time lag.

3.4 Control variables

Three variables were controlled while testing the hypotheses to account for possible extraneous effects. Previous studies investigating manufacturing performance, using IMSS data, suggest that size, country development and market dynamics can correlate with manufacturing operational performance. (e.g. Da Silveira and Sousa, 2010; Thomé et al., 2014a, 2014b; Thomé and Sousa, 2016).

First, firm size was measured by the number of employees in the business unit (SIZE, μ = 2962.96; σ =11966.7; N = 929). Due to the exponential distribution of this variable, its natural logarithm was used to improve normality (Cagliano et al., 2001; Elango 2006; Da Silveira and Sousa 2010; Vanpoucke et al., 2014; Graham and Potter, 2015; Szasz et al., 2016). Second, market dynamics were measured through the survey respondents' perceptions on a Likert scale ranging from 1 – market declining rapidly -- to 5 – market growing rapidly (MKT, $\mu = 3.28$; $\sigma = 0.85$; N = 931). Third, country development was measured by gross domestic product per capita (2013-2014 US dollar estimates), obtained from WDI online development indicators (World Bank, 2016) (GDP, $\mu = 32920.01$; $\sigma = 24701.87$; N = 931).

4
Results

This Chapter shows the results of the measurement model assessment (GOF indexes, convergent validity and discriminant validity) and tests the hypotheses using hierarchical stepwise multiple regression, in order to answer the third RQ (“How sustainability practices impact manufacturing operational performance?”).

4.1
Measurement Model Assessment

Under Anderson and Gerbing’s (1998) two-step approach for structural equation modeling, before testing the hypotheses, the measurement model was first defined and validated, using CFA, as described in Section 3.2 of this dissertation.

There are various choices of computer tools available for CFA/SEM. These include AMOS, LISREL, EQS, Mplus, among others. For this dissertation the software AMOS (Analysis of Moment Structure) was chosen because, in addition to being a module of SPSS software used for the regression analysis, it features a more friendly graphical interface for all functions, dismissing the use of syntax command or computer code (Arbuckle, 2013). In the literature review done in Section 2.1 of this dissertarion, there were a large number of studies using AMOS for their analysis. Thus, measurement models were run in AMOS 22.0, using maximum likelihood estimates.

The full model with all constructs was assessed. An initial model with all indicators, depicted in Table 11 (Section 3.3), of internal sustainability management practices, external sustainability management and operational manufacturing performance constructs (cost, quality, flexibility and delivery) resulted in unacceptable and poor GOF indexes ($\chi 2/df = 4.351$; CFI = 0.936; NFI = 0.919; TLI = 0.906; RMSEA= 0.054; CI (90%)= 0.049 – 0.060; PCLOSE = 0.079). The overall model was enhanced through the elimination of two items from INT_SUST. Deleted items are marked with an asterisk in Table 5. The refined model showed much better indexes, indicating that the measurement model fitted the data reasonably well ($\chi 2/df$ = 2.754; CFI = 0.970; NFI = 0.955; TLI = 0.953; RMSEA=0.039; CI (90%)= 0.033 – 0.046; PCLOSE = 0.997). All scales passed the test for convergent validity, with factor loads and composite reliability close or above 0.7 and AVEs above 0.5. Discriminant validity was established by verifying that AVEs' square roots were higher than inter variable correlations for all items (Fornell and Lacker, 1981; Anderson and Gerbing, 1988; Hair et al., 2010a). Figure 8 and Table 13 depict the results for the refined model.

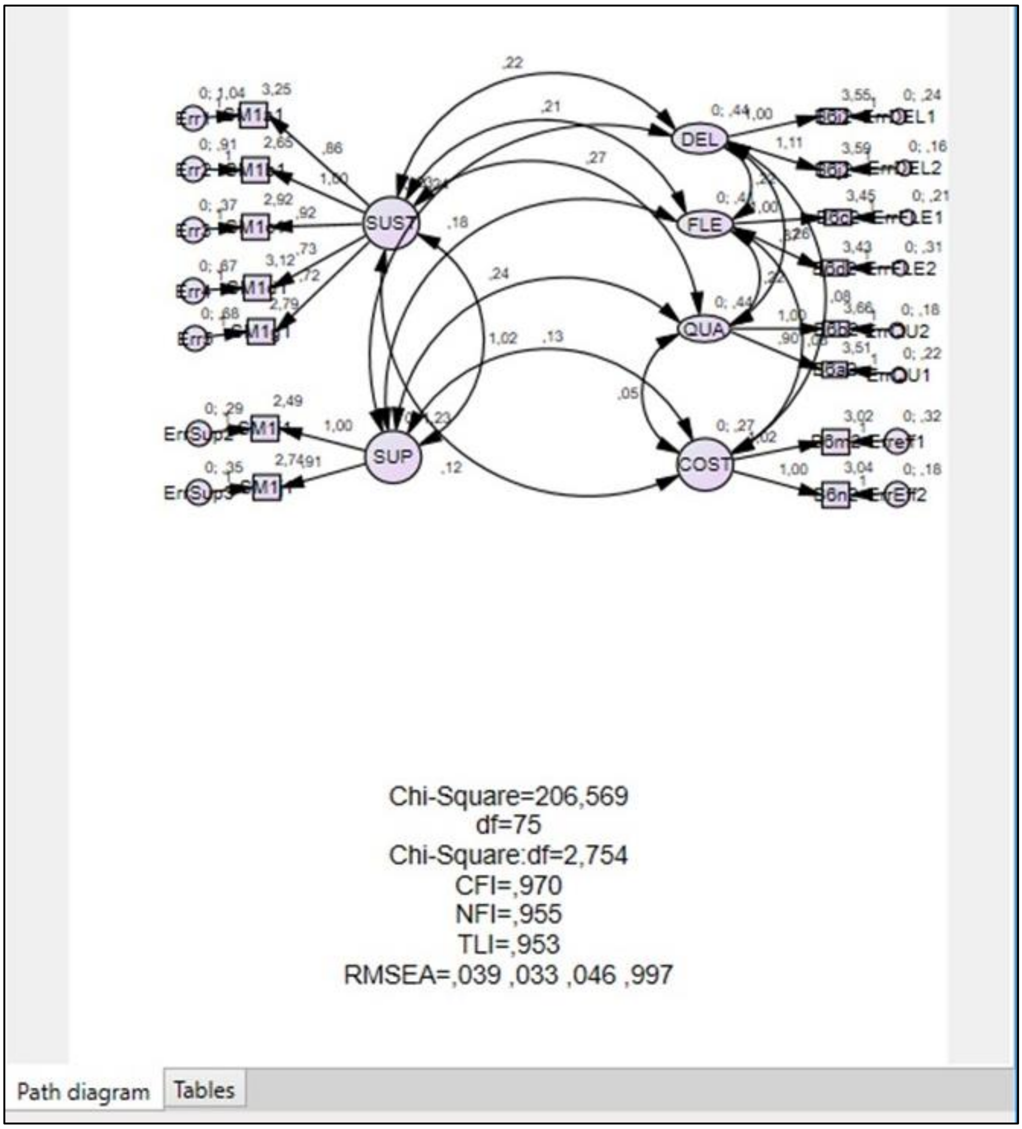

Figure 8: Final Measurement Model in AMOS 22.0

Table 13: Measurement Model Statistics

Constructs and indicators	Factor Loads	C.R.	AVE	1	2	3	4	5	6
1. INT_SUST		0.86	0.55	*(0.744)*					
Environmental certifications	0.683								
Social certifications	0.759								
Sustainability Communication	0.859								
Energy and water consumption reduction programs	0.707								
Work/life balance policies	0.698								
2. EXT_SUST		0.87	0.78	0.825	*(0.882)*				
Training/education supplier	0.900								
Joint efforts to improve sustainability	0.863								
3. COST		0.69	0.53	0.207	0.230	*(0.728)*			
Unit Manufacturing Costs	0.678								
Ordering Costs	0.774								
4. QUALITY		0.80	0.66	0.373	0.333	0.135	*(0.814)*		
Conformance quality	0.783								
Product quality and reliability	0.843								
5. FLEXIBILITY		0.73	0.58	0.300	0.253	0.257	0.524	*(0.759)*	
Volume flexibility	0.812								
Mix flexibility	0.703								
6. DELIVERY		0.83	0.71	0.293	0.308	0.233	0.604	0.520	(0.842)
Delivery speed	0.783								
Delivery reliability	0.843								

Note: AVE`s square roots in the main diagonal, in italics and parentheses. Factor loads (standardized) and correlations obtained with Amos 22.0

4.1.1
Common Method Bias

Common method variance, or common method bias, refers to spurious covariance shared among variables due to data being collected from a single informant. Common method variance can hinder the differentiation of the true variance and the false variance attributable to the data collection method (Malhotra et al., 2006). To minimize common method biases, the IMSS survey guarantees anonymity and confidentiality, questions/items are described clearly and concisely, and independent and dependent variables are collected from different parts of the questionnaire and with different scale formats. The author tested post-hoc for the existence of common method biases by conducting Harman’s single-component test (Podsakoff et al. 2003). The author loaded all 15 manifest variables in one single latent variable. The resulting model fit was poor ($\chi 2/df = 20.215$; CFI = 0.612; NFI = 0.603; TLI = 0.483; RMSEA = 0.130; PCLOSE = 0.000), suggesting the absence of common method bias.

4.2
Regression Analysis

The hypotheses were tested with hierarchical stepwise multiple regression, with control variables entered in the first step and predictors (independent variables) entered in the second step. The tests were run with SPSS 22.0.

The model was regressed separately for cost, quality, flexibility and delivery. The full regression equation was:

$$Y = \alpha + \beta_1 LNSIZE + \beta_2 MKTDYN + \beta_3 GDP + \beta_5 INT_{SUST} + \beta_5 EXT_{SUST} + \varepsilon \qquad [3]$$

Where:

- Y: dependent variable (cost efficiency, quality, flexibility and delivery performances).
- LNSIZE (natural logarithm of size): control variable
- MKTDYN (market dynamic): control variable
- GDP (gross domestic product per capita): control variable

- INT_SUST (internal sustainability management practices): independent variable
- EXT_SUST (external sustainability management): independent variable

The variables included in the regression were obtained by averaging the values of their manifest or latent variables. The analysis was performed with list wise deletion of missing values, after verifying that variables were missing completely at random (MCAR). Little's (1998) MCAR test was not statistically significant, with $p > 0.1$ ($\chi 2 = 625.117$, DF = 617).

To avoid multicollinearity, all independent variables were mean centered (Jaccard et al., 1990). Variance inflation factors (VIF) were well below 10 and condition indexes (CI) were well below 30, suggesting the absence of multicollinearity (Kennedy, 2003). Hypothesis tests were based on the significance of standardized regression coefficients and F-change. Results can be found in Table 14.

Table 14: Regression coefficients

Variables	**COST**	**QUA**	**FLEX**	**DEL**
Hypothesis tests				
Control variables				
LNSIZE	0.089**	0.025	0.044	0.045
MKTDYN	0.184***	0.223***	0.144***	0.133***
GDP	0.056	-0.124***	-0.047	-0.150***
F-Change	10.586***	17.179***	6.231***	11.004***
R^2	0.045	0.071	0.027	0.047
Adjusted R^2	0.041	0.067	0.023	0.043
Direct Effects				
LNSIZE	0.057	-0.042	-0.012	-0.005
MKTDYN	0.156***	0.177***	0.107**	0.094**
GDP	0.097**	-0.063	0.001	-0.094**
INT_SUST	0.038	0.220***	0.201***	0.103
EXT_SUST	0.135**	0.080	0.040	0.147***
F-Change	8.322***	26.513***	16.445***	16.892***
R^2	0.068	0.14	0.073	0.093
Adjusted R^2	0.061	0.133	0.066	0.086

Note: Coefficients are unadjusted standardized coefficients.
Significance levels: ** $p<0.05$; *** $p<0.001$

The R^2 (coefficient of determination) indicates the variance explained by control and independent variables. The higher the value of R^2 , the greater the explanatory power of the regression equation. The adjusted R^2 takes into account the number of independent variables and is useful for comparison between equations with different number of independent variables (Hair et al, 2010a).

The statistical significance of F-change ($p<0.001$) for the regression models in step 2 (direct effects) and the significance of standardized regression coefficients provide support for hypotheses H1b, H1c, H2a, H2d. Hypotheses H1a, H1d, H2b and H2c were not supported. Table 15 provides a summary of hypothesis tests.

Table 15: Summary of the hypothesis tests

Hypotheses	**Result**
H1a: Internal sustainability → cost efficiency	Not supported
H1b: Internal sustainability → quality	Supported
H1c: Internal sustainability → flexibility	Supported
H1d: Internal sustainability → delivery	Not supported
H2a: External sustainability → cost efficiency	Supported
H2b: External sustainability → quality	Not supported
H2c: External sustainability → flexibility	Not supported
H2d: External sustainability → delivery	Supported

5 Discussions

The results pointed to an overall positive direct relationship between internal and external sustainability management practices, but their effects on different dimensions of operational manufacturing performance varies. Internal sustainability management practices have strong positive effects upon quality (H1b: β=0.220; p<0.001) and flexibility (H1c: β=0.201; p<0.001), but there was no evidence pointing to effects on delivery (H1d not supported) or cost efficiency (H1a not supported). In opposition, external sustainability management enhances costs and delivery, but not quality or flexibility.

There was no statistical support for a direct effect of internal sustainability management practices on cost efficiency (H1a no supported). Although extant research would point to a positive effect, this dissertation finding is consistent with the results from Adebanjo et al. (2016). It is worth mentioning that the lack of statistical support does not point to the existence of a negative correlation either.

It may be that while reductions of energy consumption, material usage and waste, and use of more environmentally friendly materials lead to manufacturing efficiency (Zhu and Sarkis, 2004, Gimenez et al. 2012), the cost of implementing and maintaining other aspects of sustainability programs may neutralize such benefits in the short term. Furthermore, as pointed out by Cruz and Wakolbinger (2008), the costs of implementing waste recycling programs, training employees, and subscribing to certifications would be less in the long term compared to the costs of liability for pollution, compliance with regulation, dangerous operations, use of hazardous raw materials, production of hazardous waste, and health and safety issues.

The positive relationship between internal sustainability management practices, quality (H1b) and flexibility (H1c) was expected. Porter and van der Linde (1995) emphasized the similarities between environmental management and Total Quality Management (TQM), for instance, as they follow the same basic principles: (i) use inputs more efficiently; (ii) eliminate the need for hazardous, hard-to-handle materials; and (iii) eliminate unneeded activities. Zhu and Sarkis (2004) contributed to this idea by referring to the ISO standard certification, one of the internal sustainable practices used in this study, as Quality Management activity. Furthermore, the statistical results of this dissertation are consistent with Wiengarten et al. (2012), who found positive effects of sustainability (as combined environmental and social internal practices) on flexibility and quality in static industries. These findings may suggest that firms that implement sustainability initiatives internally can obtain sustainability credentials to command better products, achieving or overlapping customer expectations, as well as obtaining better coordination of operations capacity to improve flexibility.

The lack of a direct effect of internal sustainable practices on delivery (H1d), although counter intuitive, is consistent with Wiengarten et al. (2012), who found that investments in pollution prevention, waste management, recycling and health/safety did not provide a significant pay-off in terms of delivery, in neither static nor dynamic industries. Previous findings that found a positive link (e.g., Schoenherr, 2012) used scales of environmental dimension only and not a combined scale of environmental and social practices as it is the case of this study and Wiengarten et al.'s (2012) research. It can be hypothesized that, similarly to cost performances, social sustainability programs may hinder delivery performance in the short run and pay-off in the long run (Cruz and Wakolbinger, 2008).

The results for external sustainability management show that working with suppliers to tackle environmental and social concerns may enhance the manufacturing performance of the firm in terms of costs efficiency (H2a: β=0.135; p<0.001) and delivery (H2d: β=0.147; p<0.001), but not for quality (H2b not supported) and flexibility (H2c not supported); at least not in the short term.

The positive effect of external sustainability management on cost efficiency (H2a) is consistent with previous research (Rao and Holt, 2005; Paulraj and De Jong, 2011; Yu et al., 2014; Graham and Potter, 2015). These results demonstrate the importance of supply chain collaboration, since implementing sustainable practices exclusively within the company may not be as effective as integrating practices into the chain. Nonetheless, when analyzing effectiveness dimensions, only delivery (H2d) was affected. Although Vachon and Klassen (2008) and Yu et al. (2014) found positive effect on quality and flexibility besides delivery, this dissertation's results were consistent with Yang et al. (2010). The findings suggest, then, that working with suppliers on sustainability issues facilitates order fulfillment with speed and reliability and also contributes to cost efficiency, but makes no differentiation for quality and flexibility, which might be already affected by internal sustainable practices.

It is worth to remember that the literature review in Section 2.1 showed that internal sustainability management practices construct is a relevant antecedent of external management practices. Therefore, internal and external sustainable practices seem to work in a complementary fashion to achieve competitive advantage in terms of operational outcomes. It is therefore likely that implementing both internal and external sustainable practices simultaneously will generate a positive impact on overall operational performance.

Several explanations may justify mixed results in the literature. First, there are different timeframes for the analysis. Some authors use the same year to compare practices and performance (e.g. Gimenez et al., 2012; Szasz et al., 2016) but, as aforementioned, the benefits of sustainability practices might only appear years later. Second, sustainability management includes a wide range of practices. The use of different measures of sustainability management might naturally leads to differing results. Third, sample sizes varies across studies and may lead to inconsistent results in studies with small samples. Fourth, diverse industry contexts should also originate different results. Previous research has identified that the degree to which various management practices or strategies affect a firm performance depends on several contextual factors (e.g., Das et al., 2000; Voss and Blackmon, 1998; Ward and Duray, 2000; Sousa and Voss; 2008). Fifth, another possible explanation is the inability of firms to associate operational benefits to sustainability practices by not having an effective monitoring system or indicators that can directly link the practices to improvements on operational outcomes.

Although it is not the primary focus of this study, results related to the control variables are worth noting (step 1 in Table 14). Country-level economic development has a direct negative effect on quality (β=−0.124; $p<0.001$) and delivery (β=−0.150; $p<0.001$), but no significant effect on flexibility and cost efficiency. These results are consistent with Schoenherr (2012) and Szasz et al. (2016), among others. This might occur because developed countries attain higher levels of effectiveness and, therefore, their direct effects are less evident than in countries that have lower levels of performance (Meijboom and Vos, 1997; Gupta and Govindarajan, 2000; Ambos et al., 2006; Szasz et al., 2016).

Market dynamics showed a significant positive impact on all performance dimensions (cost efficiency: β=0.184; quality: β=0.223; flexibility: β=0.144; delivery: β=0.133; $p<0.001$). Findings are consistent with the expectation that companies operating in fast growing markets should show greater performance (Landsom, 2000; Da Silveira and Sousa, 2010).

Finally, firm size has a direct positive effect on cost efficiency (β=0.089; $p<0.05$). The lack of a significant relationship with other dimensions (quality, flexibility and delivery) was not a surprise. Although previous studies (Fiegenbaum and Karnani, 1991; Jack and Raturi, 2003; Rodchua, 2009) have suggested that size may have either positive or negative correlations with performance in areas such as quality and flexibility, these findings are consistent with recent studies (Da Silveira and Sousa, 2010; Thomé et al., 2014a; Szasz et al., 2016). According to Cagliano et al. (2001), in general, size is linked with significant differences in manufacturing practices and only to a lesser extent in manufacturing performance.

6
Conclusions and future research

This dissertation offered an empirical research combined with a bibliographic analysis of the theme of sustainability in OM literature in order to answer three research questions (RQs): (i) How empirical research analyses causal models of sustainability? (ii) How OM defines sustainability? and (iii) How sustainability practices impact manufacturing operational performance?

Answers to the first RQ provide a comprehensive view of the factors that influence the relationship between sustainability and firm performance, in terms of determinants, mediators and moderators. The use of statistical techniques to confirm theories around this topic has been growing over the last decade.

Answers to the second RQ provide discussion around the term sustainability applied to the field of OM. Studying sustainability is essential, as manufacturing firms have to account for energy, water and other natural resources to produce and hence generating high level of footprint and impact on the external community.

Regarding the third RQ, structural equation modeling was used to better understanding the relationship between sustainability management practices (internal and external) and manufacturing operational performance (costs, quality, flexibility and delivery). Our contentions were grounded on the resource-based view of the firm (RBV) and its extension, the natural resource-based view (NRBV). The hypotheses were tested with IMSS-VI data collected from 674 plants with complete information, located in 22 countries.

The author found that internal and external sustainability management practices are complementary and, when implemented, will probably affect operational manufacturing performance positively. Internal sustainable practices showed positive correlation with quality and flexibility dimensions, while external sustainability management contributes to reduce costs and enhance delivery performance.

In summary, there are significant practical and research contributions. First, a multi-country survey was used to statistically test the impact of sustainability management practices, distinguishing internal and external practices and covering the impact of both environmental and social dimensions on operational performance, measured with multiple dimensions (cost, flexibility, delivery and quality). As a result, this provided a holistic understanding of this relationship, filling a gap of the literature research on sustainability in the OM field by the use of a holistic definition of sustainability (environmental and social) and the analysis of its effects in the multiple dimensions of operational performance.

Second, by analyzing the role of suppliers’ collaboration (external sustainability management), this study’s framework was extended to the supply chain. The positive linkage between internal sustainable practices, suppliers’ collaboration and different dimensions of manufacturing performance add further support to the growing body of literature espousing the NBRV in asserting the natural environment as a valuable, rare, inimitable and non-substitutable resource, leading to competitive advantages. Statistical results complement and expand upon previous research and further contribute to theory.

From a practitioner’s point of view, results suggest that implementing sustainable practices may lead to better operational performance, although internal sustainability management by itself may not reduce manufacturing costs; at least not in the short run. Managers should understand the positive impact of joint efforts with suppliers, in fulfillment of the internal adoption of sustainable practices in order to reduce costs and enhance delivery, flexibility and quality and, thus, contributing to the operational efficiency and effectiveness of the firm.

Further research on the consequences of sustainable practices on firm performance could provide additional insights and encourage managers to act, not in compliance with the law, but also proactively, developing innovative solutions to environmental and social challenges, and, in turn, benefiting from improvements in other facets of the organization’s operations. Ultimately, firms would contribute positively to society through actions such as the development of social initiatives and the creation of health and welfare for people; also through safeguarding the environment and its integrity for future generations. Therefore, implementing sustainability practices could be a win-win proposition for both individual firms and society as a whole.

This study's limitations lead to suggestions for future research. First, this research is focused on assembly industries. Future research should access whether the statistical results hold for different types of industries. Second, the impact of sustainability on performance could be extended beyond operational measures of performance and into market share and financial performance (e.g. return on sales and return on investment) of the firm. According to Beneditez-Amado et al. (2015), sustainable operations enhance product and process innovation, have a better reputation, and have more legitimacy and recognition from regulators and society, enabling them to access more markets and, therefore, potentially increase sales and revenues. Third, collaboration with customers when implementing sustainability management practices in the supply chain (e.g. green packaging and product transportation) could integrate the analysis (Yu et al. 2014). Finally, the analysis could also be enriched by including mediating or moderating variables. Results from the Chapter 2 suggest that pressure commitment to sustainability, environmental and social performances, among others, could interfere in the relationship between sustainability practices and operational performance.

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Appendix I – Mathematical expressions for the fit indexes

The **Comparative fit index (**CFI) is defined as:

$$CFI = 1 - \frac{\max[(\chi_t^2 - df_t),0]}{\max[(\chi_t^2 - df_t), (\chi_i^2 - df_i), 0]} \qquad \text{(A-1)}$$

Where

Max denotes the maximum of the values given in the brackets,

χ_i^2 is the chi-square of the independence model (baseline model)

χ_t^2 is the chi-square of the target model, and

df is the number of degrees of freedom

(Schermelleh-Engel and Moosbrugger, 2003)

The **Normed-fit index (**NFI) is defined as:

$$NFI = \frac{\chi_i^2 - \chi_t^2}{\chi_i^2} = 1 - \frac{\chi_t^2}{\chi_i^2} = 1 - \frac{F_t}{F_i} \qquad \text{(A-2)}$$

Where

χ_i^2 is the chi-square of the independence model (baseline model)

χ_t^2 is the chi-square of the target model, and

F is the corresponding minimum fit function value

(Schermelleh-Engel and Moosbrugger, 2003)

The **Tucker-Lewis Index (**TLI) is defined as:

$$TLI = \frac{(\frac{\chi_i^2}{dfi}) - (\frac{\chi_t^2}{dft})}{\frac{\chi_i^2}{dfi} - 1} \quad \text{(A-3)}$$

Where

χ_i^2 is the chi-square of the independence model (baseline model)

χ_t^2 is the chi-square of the target model, and

df is the number of degrees of freedom.

(Schermelleh-Engel and Moosbrugger, 2003)

RMSEA is estimated by $\hat{\varepsilon}_a$, the square root of the estimated discrepancy due to approximation per degree of freedom:

$$\hat{\varepsilon}_a = \sqrt{\max\left\{\left(\frac{F(\mathrm{S}, \sum(\hat{\theta})}{df} - \frac{1}{N-1}\right), 0\right\}} \quad \text{(A-4)}$$

where

F(S, $\sum(\hat{\theta})$) is the minimum of the fit function

df is the number of degrees of freedom, and

N is the sample size

(Schermelleh-Engel and Moosbrugger, 2003)

Appendix II – Guideline for fit indexes

Table A 1: GOF across different model situations

GOF indexes	N<250			N>250		
	m<=12	**12<m<30**	**m>=30**	**m<=12**	**12<m<30**	**m>=30**
χ2	Insignificant p-values expected	Significant p-values even with good fit	Significant p-values expected	Insignificant p-values even with good fit	Significant p-values expected	Significant p-values expected
CFI or TLI	0.97 or better	0.95 or better	Above 0.92	0.95 or better	Above 0.92	Above 0.90
RMSEA	Values < 0.08 with CFI = 0.97 or higher	Values < 0.08 with CFI of 0.95 or higher	Values < 0.08 with CFI above 0.92	Values < 0.07 with CFI of 0.97 or higher	Values < 0.07 with CFI of 0.92 or higher	Values < 0.07 with CFI of 0.90 or higher

Note: m=number of observed variables, N applies to number of observations per group when applying CFA to multiple groups at the same time

Source: Hair et al. (2010a, p.647)