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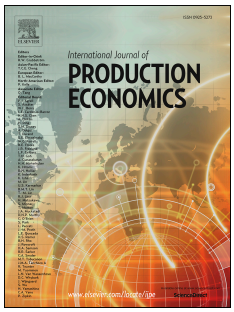

A meta-analytical study of the impact of Lean Practices on firm performance

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A meta-analytical study of the impact of Lean Practices on firm performance

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A meta-analytic study of the impact of Lean Production on business performance

Abstract

Lean Production (LP) is one of the most common initiatives in Operations Management that firms adopt to boost their competitiveness. The purpose of this paper is to examine the extant research on the relationship between LP and business performance (BP). The study analyses the data from 30 articles published from 2000 to 2016 that meet two targeted criteria, that they have: (i) empirically analysed the relationship between LP, or any measure of LP, and at least one measure of BP, and (ii) reported the effect size of the relationship between LP and BP measured with Pearson's correlation coefficients or related methods. Distinctions are made between two different performance outcomes (financial and market) and six LP practices. Using the Hunter and Schmidt (2004) meta-analysis based correlations approach, the obtained results show that a positive and moderate relationship exists between aggregate level LP and aggregate level business performance ($\bar{r}$ = 0.31). There is also a positive relationship with market performance, but not with financial performance. Only three individual practices are statistically related to business performance (Process Control and Improvement, Workforce Development, and Customer Focus). The country's level of economic development is also found to act as a moderating variable in several of the studied relationships and to have a greater effect in Emerging Economies than in Advanced Economies.

Keywords: Lean Production; Business Performance; Financial Performance; Market Performance; Meta-analysis

1. Introduction

Firms need to continuously improve to compete in an increasingly globalized environment and in recent decades new approaches have emerged to this end in the operations area (Cua et al., 2006; Flynn et al., 1995; Fullerton et al., 2014; Fullerton and Wempe, 2009; Shah and Ward, 2003- 2007; Yang et al., 2011). One of the best known of these is Lean Production (LP) (Hines et al., 2004; Camacho-Miñano et al., 2012 ; Bhamu and Sangwan, 2014).

LP has been defined as an integrated set of socio-technical practices designed to eliminate waste along the whole of the value chain within and across companies (Womack et al., 1990; Holweg, 2007). Since its introduction, the lean approach has increasingly expanded in the field of operations management until it has now become a fully holistic business strategy. Lean involves nearly all aspects of the organisation. Numerous tools, techniques and practices have been developed over time for this approach to be implemented, and many others that already existed have easily slotted into Lean's broader focus. Many of these LP practices have been integrated into extensive packages or focuses related to aspects such as quality (total quality management, TQM), production flow (just-in-time production, JIT) and maintenance (total productive maintenance, TPM) (Cua et al., 2006; Shah and Ward, 2003; Furlan et al., 2011a; Dal Pont et al., 2008).

Firms that espouse LP benefit from many advantages (manufacturing costs, productivity, inventory turnover, lead time, on-time delivery, fast delivery, flexibility, quality, space requirement, etc.). In fact, studies of LP have traditionally been associated with an analysis of its impact on operational performance (e.g., Shah and Ward, 2003; Dal Pont et al., 2008; Fullerton and Wempe, 2009)). The benefits have usually been measured using operational performance measures, perhaps because they can be monitored at plant level, which is the unit where LP is generally applied (Abdel-Maksoud et al., 2005; Nawanir et al., 2013)

Some meta-analytic studies were found in the reviewed scientific literature (Nair, 2006; Mackelprang and Nair, 2010) that confirm positive relationships between some of the dimensions of Lean (specifically JIT and TQM) and operational performance.

The LP-business performance (expressed as financial and market performance) relationship has also been empirically studied. Despite a number of relevant studies finding that LP has a positive effect on performance (Brah et al., 2000; Kaynak, 2003; Yang et al., 2011, Agus and Hajinoor, 2012; Hofer et al., 2012), some controversy still exists as to its general applicability (Kannan and Tan, 2005; Avittathur and Swamidass, 2007; Jayaram et al., 2008; Camacho-Miñano et al., 2013; Klingenberg et al., 2013). This, and the fact that no meta-analysis has been conducted of this relationship, was the motivation for the present research.

As Shah and Ward (2003) state, it should be borne in mind when analysing the benefits of LP that 'Lean production is a multi-dimensional approach that encompasses a wide variety of management practices… in an integrated system'. So, although LP implementation only actually happens through the application of an array of practices, the overall result is not simply the sum of the outcomes of each of these. To the contrary, these practices complement and mutually support each other, creating synergistic effects that boost the benefits to the company. Several authors (Womack and Jones, 1996; Schroeder and Flynn, 2002; New, 2007) examine complementarity among the various lean practices and their positive effect on performance from the theoretical point-of-view. However, the majority of empirical studies with similar aims have sought to study the effect of this complementarity or interrelationship on operational performance (Shah and Ward, 2003; Dal Pon et al., 2008; Furlan et al., 2011a-2011b, Konecny and Thun, 2011).

Empirical studies analysing the effect of this synergy on financial or market performance are extremely scarce. However, Hofer et al. (2012) determined that the simultaneous implementation of internally-focused and externally-focused lean practices has a positive effect on financial performance (with ROS as the indicator). We therefore consider that conducting a meta-analysis of the relationship between lean practices and business performance that considers any possible interdependencies among the various lean practices might help to fill this gap and thus enhance the scientific literature in this respect.

The purpose of this study is, therefore, to conduct a meta-analysis to help clarify the relationship between LP implementation (in general, and of the main lean practices individually) and business performance using financial and market performance indicators. The aim is to synthesize the empirical evidence available to date and provide some direction to future research efforts. The study seeks to respond to the following three research questions on the LP-business performance relationship in particular:

a) Is LP (as an aggregate, considering any interrelationships among lean practices) positively correlated with (financial and market) business performance? If so, how strong is the relationship?
b) Which LP practices have a stronger impact on business performance?
c) Is this relationship homogenous or is it affected by any moderators?

The paper answers these questions using a meta-analysis of correlations approach with data taken from research studies published in 2000 or later, and follows the Hunter and Schmidt (2004) procedure. Meta-analysis is a powerful method for conducting systematic syntheses of empirical literature, as it enables conflictive findings to be resolved and the potential sources of these conflicts to be evaluated through moderator analyses (Card, 2012).

The paper is structured in 6 sections. Following this Introduction (Section 1), a brief review of the literature on the LP-Performance relationship is given in Section 2. Section 3 describes the research methodology, including details of the sample and the methods used for the analysis. The main research results are then presented in Section 4, followed by the discussion in Section 5 and conclusions in Section 6.

2. Literature review

This section begins with a brief reference to the origins and development of Lean Production and a discussion on how LP implementation has been measured in the literature. This is followed by an analysis of the LP–business performance relationship and the identification of the main dimensions used to measure lean practices. Next, some of the factors are discussed that, as moderators or control variables, might affect the LP-BP relationship. Lastly, the research model is presented and the hypotheses that are to be tested are formulated.

2.1. Lean Production: evolution and implementation

Although LP did not become popular until the beginning of the 1990s, the literature on Lean Manufacturing can be traced back to the 1970s. Several works have analysed Lean's origins and development, either through historical or conceptual reviews (e.g., Shah and Ward, 2007; Hines et al., 2004; Holweg, 2007; New, 2007) or through literature reviews (e.g., Pettersen, 2009; Moyano-Fuentes and Sacristán-Díaz, 2012; Stone, 2013; Camacho-Miñano et al., 2013; Bhamu and Sangwan, 2014; Negrão et al., 2017). Stone (2013) identified five phases of lean evolution: Discovery phase (1970-1990); Dissemination phase (1991-1996); Implementation phase (1997-2000); Enterprise phase (2001-2005); and Performance phase (2006-2009). The same author explained that during the late 1990s and early 2000s the focus shifted from implementing lean exclusively on the manufacturing shop floor to its application in other areas of the enterprise (Stone, 2013). In an extensive literature review, Bhamu and Sangwan (2014) differentiated between four periods: a) origin and development (pre 1994), b) wider dissemination (1994-1999), c) propagation into product development, marketing, sales, service, accounting, etc. (2000-2005), and d) performance phase and development of new principles (2006 onwards). According to these authors, up to 2000 the predominant research methodology was conceptual and descriptive, but then went on to be for the main part more empirical and exploratory. In the same line, Shah and Ward (2007) considered the 1988-2000 period as one of academic progress.

The Lean concept has gradually spread beyond manufacturing (Lean Manufacturing) and Lean management is currently spoken of as an organisational philosophy based on the principles of the elimination of wastage and an increase in value for the customer. However, the present study focuses on Lean Production, which refers to a set of production- and/or service-related lean practices inspired by the foregoing principles. We regard Lean Production as an extension of Lean Manufacturing that can also be used in service companies.

Apart from a holistic management focus based on a number of objectives and principles (Womack and Jones, 2003; Liker, 2006), Lean also encompasses a set of practices, tools, techniques and methodologies that enable objectives to be met through the application of these principles. However, Bhamu and Sangwan (2014) found that there is no standard LP implementation framework and no dedicated LP implementation tools, techniques, or methodologies exist, but, rather, most of these are standalone matured tools, such as 5S, six sigma, TPM, JIT, VSM, kaizen, etc. A very high number and great variety of these practices have been identified in the literature to measure LP implementation (see Appendix A). Nawanir et al. (2013) states that although many researchers and practitioners have attempted to identify the main LP practices, there is no single agreement among them regarding the relative importance of the practices. Moreover, some LP tools and techniques have multiple names and overlap with others (Bhamu and Sangwan, 2014).

Malmbrandt and Åhlström (2013) drew up a table with an overview of ten instruments to assess lean manufacturing adoption that they had found in the literature. With the aim of developing an instrument to measure the degree of Lean Implementation in manufacturing, Herzog and Tonchia (2014) identified 24 variables that they grouped in 8 areas: 1.The value concept and customers; 2.

VSM; 3. Pull/kanban + flow; 4. Waste elimination; 5. Productive maintenance; 6. Just-in-time; 7. Employee involvement; and 8. Lean suppliers. Eswaramoorthi et al. (2011) examined the implementation of 36 LP tools in Indian machine industries. One of the best-known and most cited works on the measurement of Lean implementation is probably the Shah and Ward (2007) study. These authors used a literature review to develop an instrument that represented lean that contained 48 subsequently empirically validated items and 10 components. The 10 components were in turn grouped into three large blocks: a) supplier related; b) customer related; and c) internally related. In an earlier study, Shah and Ward (2003) identified 22 items that they classified into 4 bundles: JIT, TPM, TQM and HRM. Camacho-Miñano et al. (2013) agreed with these four bundles to which they added a fifth related to accounting: ABM (Activity-Based Management). Moyano-Fuentes and Sacristán-Díaz (2012) classified the literature on LP into four blocks: internal aspects, value chain, work organisation, and geographical context.

Most of the studies operationalised LP as a multi-dimensional construct (Fullerton and Wempe, 2009) and this study takes the same approach. Consistent with the extant literature, this research focuses on the six practices most used in empirical analyses to relate Lean to business performance. Thus, the following six dimensions or practices are considered to be part of the Lean Production construct:

1. *Process Control & Improvements*: The extent to which quality is ensured through the use of a range of tools such as problem solving methods, statistical process control, failure mode effects analysis, fool proofing, sampling and inspection.
2. *Just-in-time Flow*: A set of interrelated practices for managing the production flow. Five JIT practices are included: setup reduction time, equipment layout, pull production, small lot and uniform production level.
3. *Workforce Development*: The extent to which the management of employees is based on empowerment, teamwork, individuals' work-related knowledge and skills, performance evaluation, and reward and recognition.
4. *Maintenance Management*: The extent to which proper maintenance activities achieve a high level of equipment availability.
5. *Customer Focus*: The extent to which the firm is focused on customer needs.
6. *Supplier Relationship*: The extent to which the firm works closely with suppliers in order to ensure that they provide the right quantity and quality at the right time and in the right place.

This division of practices into 6 groups is, in our opinion, a suitable framework for analysing LP implementation for the objectives of this research. A more exhaustive relationship with tools and techniques that would go into finer detail would have raised the number of analyses that had to be done and reduced the size of the samples. This grouping is also consistent with many previous studies and sufficiently comprehensive, and also includes the underlying constructs of the measurement instrument proposed by Shah and Ward (2007). Items 1 to 4 are the internal elements (which also coincide with the Shah and Ward (2003) and Camacho-Miñano et al. (2013) grouping except for the accounting item, ABM, in the latter case), and the last two refer to the external value chain (Moyano-Fuentes and Sacristán-Díaz, 2012) and, moreover, coincide with Shah and Ward's (2007) other two underlying constructs. Moreover, these 6 dimensions are sufficiently broad to encompass the majority of the individual techniques and tools in the existing literature.

2.2. Lean Production and Business Performance

With regard to lean performance, the focus has shifted from quality (in the literature of the early 1990s), through quality, cost and delivery (late 1990s), to customer value from 2000 onwards (Hines et al., 2004). Since Lean application has been extended to the entire company since 2000, its

impact must be evaluated not only with operational indicators (such as quality, cost, delivery and flexibility), but also more general indicators, such as financial, market, business and competitive indicators.

Authors that advocate LP state that lean offers a large number of benefits (Bhasin, 2008): shorter cycle time; shorter lead time; lower WIP; faster response time; lower cost; greater production flexibility; higher quality; better customer service; higher revenue; higher throughput; and increased profit. However, the real benefits of lean are difficult to quantify (Bhasin, 2008). Accounting systems and traditional metrics do not cater for measuring Lean's real impact and some authors have called for changes to be made to the accounting system to adapt to the use of Lean (Callen et al., 2005; Harris and Cassidy, 2013; Fullerton et al., 2014). The fundamental problem is that traditional metrics do not account for the real value of an organisation's intangible and intellectual assets (Bhasin, 2008). This study therefore proposes applying the Dynamic multidimensional performance (DMP) framework (Maltz et al., 2003), which is an extension of the balance scorecard focus (Kaplan and Norton, 1996), to a full evaluation of LP. The framework has five performance dimensions:

- financial performance: the traditional approach to organisational success;
- market/customer: the relationship between the organisation and its customers;
- process: the organisation's efficiency and improvement;
- people development: employee skills, commitment and personnel development;
- future: measures that show future value creation.

In existing LP research, performance has mainly been measured using plant level operational indicators (i.e., process), such as inventory, cycle time, delivery performance and flexibility. The impact of LP on other, company level performance dimensions has also been measured, albeit to a lesser extent. Some articles conceptualise business performance as Return on Assets and Return on Sales, Return on Investment, Profit, and Profit growth; i.e., financial performance (Inman et al., 2011, Ghobakhloo and Hong, 2014), while on other occasions it has been measured in terms of Market Share, Sales Growth, etc., i.e., market/customer performance (Curkovic et al., 2000, Ahmad et al., 2004, Yang et al., 2011). The other dimensions of business performance -people development and preparation for the future- are much less common in existing research.

As the LP-operating performance relationship has already been the object of meta-analysis (Mackelprang and Nair, 2010), performance has been conceptualised with two dimensions in the present study: financial performance (e.g., profit margin, return on sales, return on assets, and return on investment) and market performance (e.g., market share, sales, and sales growth). This approach is consistent with previous research (Narasimhan and Kim, 2002; Lin et al., 2005; Menor et al., 2007; Yang et al., 2011). In this study 'Business performance' is defined as the sum of financial performance and market performance.

Financial performance is important as, essentially, it continues to be the basis for senior managers' base investment decisions. Most of the empirical evidence shows that LP is positively related to business performance (Kaynak, 2003, Ahmad et al., 2004, Nawanir et al., 2013, Fullerton et al., 2014), but there is no lack of studies that find no empirical support for this relationship (Balakrishnan et al., 1996; Avittathur and Swamidass, 2007; Jayaram et al., 2008). In relation to financial performance, for example, Camacho-Miñano et al. (2013) conduct a literature review of empirical studies between 1992 and 2011 to determine the impact of LP on financial performance, and find 23 articles in which the relationship is positive (almost 70% of the analysed articles); 5 with mixed results, and another 5 that found no relationship.

As Hong et al. (2014) state, it is also reasonable to expect that the outcomes of lean

manufacturing practices would have some positive impact on BP, such as sales growth and market share (Narasimhan and Kim, 2002; Menor et al., 2007). Yang and Hong (2011) argue that Lean manufacturing can enhance firms' market performance by increasing customer responsiveness and reducing customer lead time, as well as enhancing the firm's ability to improve customer value in terms of lower prices and quality products.

Nawanir et al. (2013) indicatethat LP practices are believed to encourage higher profits (Green and Inman, 2007; Yang et al., 2011), outstanding sales (Green and Inman, 2007; Yang et al., 2011), and greater customer satisfaction (Abdallah and Matsui, 2007; Chong et al., 2001). However, Chavez et al. (2015) state that, while lean operations have generally been shown to be associated with improved organisational performance (i.e., market-and financial oriented performance), there are also other studies that offer mixed results.

2.3. Moderators in the LP-BP relationship

The relationship under study is very broad, due to both the independent variable, LP, on the one hand, and the dependent variable, business performance, on the other. LP covers a broad set of practices, which means that implementation can vary greatly, and, at the same time, be applied in a population of very different companies and sectors. In addition, business performance can be measured in many different ways and, above all, is influenced by many other factors, apart from LP, which are difficult to isolate. This all leads to the idea that there is no single fixed effect in reality, but that LP-BP effects are vastly heterogeneous, due to multiple moderating factors. This is in line with Contingency Theory (Lawrence and Losrch, 1967), which suggests that organisational success depends on the closeness of the fit between the organisation and the characteristics of its contextual situation.

The Mackelprang and Nair (2010) study includes a long list of possible moderating (or contextual) variables in the LP–BP relationship. These authors classify these factors on five different levels, as shown in Table 1.

Table 1. Some potential moderating factors in the LP-BP relationship.

Level	Potential moderating (or contextual) variables	Examples of studies
Lean implementation	• Different bundles of practices	⇨ Danese et al. (2012)
	• Time that practices have been in use	⇨ Agus and Iteng (2013)
Plant	• Plant size	⇨ Shah and Ward (2003), Danese et al. (2012)
	• Plant age	⇨ Shah and Ward (2003)
	• Unionisation	⇨ Shah and Ward (2003)
	• Geographical location (national culture and development level)	⇨ Moyano-Fuentes and Sacristán-Díaz (2012), Kull et al. (2014)
Company	• Organisational structure	⇨ Rahman et al. (2010)
	• Organisational culture	⇨ Pakdil and Leonard (2015)
	• Company size	⇨ Agus and Iteng (2013), Khanchanapong et al. (2014)
Industry	• Sector	⇨ Danese et al. (2012), Eroglu and Hofer (2011)
	• Type of industry (process)	⇨ Shah and Ward (2003), Khanchanapong et al. (2014)
	• Competitive intensity	⇨ Azadegan et al. (2013)
	• Environmental uncertainty	⇨ Azadegan et al. (2013), Chavez et al. (2015)
Supply Chain	• Power within the supply chain • Relationship with suppliers and customers • Communication network	

Source: Based on Mackelprang and Nair (2010)

Indeed, some studies show that the LP-business performance relationship is moderated by a range of factors. For example, Shah and Ward (2003) addressed three organisational characteristics: unionisation, plant size, and plant age. In his study of Lean performance in large organisations, Bhasin (2012) considered geographical location, size, organisation age, length of time since Lean introduction, degree of process intricacy, and extent of product complexity. Moori et al. (2013) find a positive relationship between lean manufacturing and business performance when they consider competitive skills as a mediating variable. In the same line, the present study considers the possible moderating effect of three factors, in particular the country's degree of economic development, the company sector involved (manufacturing or services) and time.

Moyano-Fuentes and Sacristán-Díaz (2012) find a group of papers that analyse the effect of the geographical context on LP and suggest that the different results that derive from LP adoption are related to the country's economic context. The geographical context comprises a variety of factors, such as national culture and the host country's level of economic development. Some studies, such as Yang et al. (2011), Hong et al. (2009), Hong and Roh (2009) and Frohlich and Dixon (2001), posit the idea that regional differences and differences in GDP[1] per capita might be contextual factors that affect both the implementation of lean practices and business performance. For example, Hong et al. (2014) find differences between developed and developing countries in the relationship between Lean and other practices, and operational performance.

[1] GDP: Gross Domestic Product

Industry is a classic contextual variable in empirical OM studies. Industries possess many features that might influence both the degree of Lean implementation and its impact on business performance. Examining the relationship between *leanness* and firm performance using a large panel data set for manufacturing companies in the US, (Eroglu and Hofer, 2011) found that the relationship varies substantially from one industry to another with regard to both significance and form. Many of the Lean tools are more applicable in certain types of productive processes. For example, Shah and Ward (2003) reported that firms in discrete industries are somewhat more likely to implement JIT practices. Some studies have focused on the industry's specific characteristics, including Azadegan et al. (2013), who investigated the way that environmental context (complexity and dynamism) influences the effect of lean operations and lean purchasing on the plant's performance. Another study by Chavez et al. (2015) showed that lean has a positive effect on both operational performance and organisational performance in industry environments where technology change is not spectacular.

It is also possible that the impact of lean practices might vary (improve) over time due to the accumulation of knowledge and experience around their implementation. As Lean has spread to more companies and sectors, there could have been a learning effect that facilitates the success of subsequent implementations in other companies. Similarly, this time variable might reflect the effects of moderating variables on the Lean implementation level. In other words, as time progresses from a company's first steps in Lean, more practices are applied, and their use further perfected, which means that business performance could gradually improve. Other studies have also used time as a moderating variable, e.g., Chang et al. (2015) in a meta-analysis of the supply chain integration-firm financial performance relationship.

2.4. Research model and hypotheses

In light of the above, Figure 1 shows the research framework and the hypotheses that the present research seeks to test by meta-analysis. The main and most general hypothesis relates to our first research question: whether LP as a whole, i.e., as an aggregation of interrelated and interdependent practices, affects business performance:

> H_1: Lean production (as an aggregate construct that takes into account interdependencies among the practices of which it is composed) is positively related to firm performance.

As stated previously, this study focuses on six LP practices that have been the most used in empirical research on the LP-performance relationship. Given the different nature of the practices used to measure LP implementation, it makes sense to analyse the relationship of each of these practices separately in order to determine those that have a greater impact (this is the second research question). This gives rise to six hypotheses that posit the existence of a positive relationship between the implementation of each of the six individual LP practices and business performance:

> H2: Process Control & Improvements are positively related to business performance.
> H3: Just-in-time Flow is positively related to business performance.
> H4: Workforce Development is positively related to business performance.
> H5: Maintenance Management is positively related to business performance.
> H6: Customer Focus is positively related to business performance.
> H7: Supplier Relationship is positively related to business performance.

In addition, this study considers business performance as an aggregate of two different types of performance: financial and market. Bearing in mind the multidimensional nature of the business performance concept, differences may exist between the impacts of LP on each of these two performance dimensions. The fact that the relationships with the two performance dimensions generate two new sets of sub hypotheses for the above-formulated hypotheses (H1a to H7a, for the relationships with financial performance, and H1b to H7b, for market performance) enables the two above research questions to be investigated in greater depth, making a distinction between the impact of LP on the aggregate level, and of each of its individual practices on financial and market performance.

Lastly, our model also includes three contextual moderating variables that are analysed in all of the above relationships. We are thus able to address the third and last research question, and so use these to explain any heterogeneity that may exist.

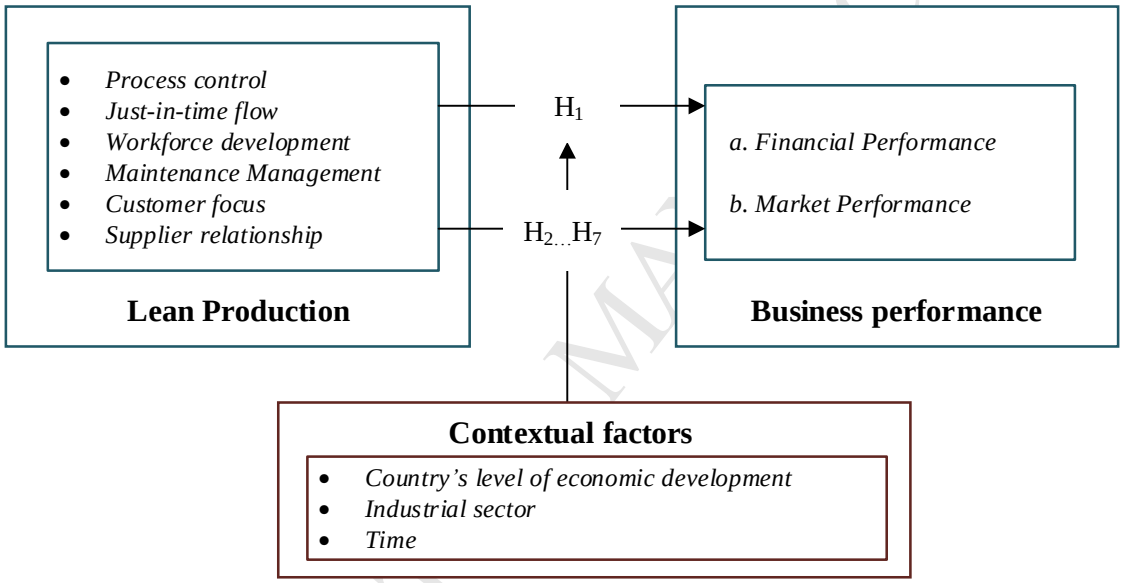


Fig. 1 Research framework**.**

3. Research methodology

3.1. Meta-analysis of correlations

Meta-analysis of correlations methodology gives an insight into a phenomenon by describing the distribution of actual correlations between independent and dependent variables (Hunter and Schmidt, 2004), and has been shown to be effective in providing quantitative descriptions in the field of operations management (Gerwin and Barrowman, 2002; Nair, 2006; Mackelprang and Nair, 2010; Yu et al., 2015; Ataseven and Nair, 2017; Geng et al., 2017). This methodology is widely viewed as a necessary component of scientific inquiry and theory building (Rosenthal and Rosnow, 1991; Hunter and Schmidt, 2004). Card (2012) points out that the advancement of scientific knowledge is based on the principles of replication and accumulation, and argues that 'many areas of social science research are in less need of further research than they are in need of

the organisation of existing research'. A sufficient number of empirical studies of the relationship between LP and business performance would seem to have accrued for an overall analysis to be conducted using the meta-analysis technique.

The following describes the literature search procedures and the method used to obtain the final sample. Subsequently, an explanation is given of the process followed to code the study characteristics and effect sizes. Lastly, a description is given of the data analytic strategy and methods.

3.2. Sample

A three-stage literature review was conducted (see Figure 2).

Stage 1. Database search. Inclusion criteria: a detailed computer search was performed in ABI/INFORM[2] including articles published post 2000. The combined following keywords were used in the search: '*Total Quality Management'; 'TQM'; 'Quality Programs'; 'quality management practices'; 'Just-in-time'; 'Total Productive Maintenance'; 'Lean Manufacturing/Production Practices';* and '*financial performance'; 'market performance'; 'business performance'; 'firm performance'; and 'organisational performance'*. The search produced 740 articles published in journals, of which 101 were duplicated in databases and were eliminated.

Stage 2. Exclusion criteria: two exclusion criteria were applied to the 639 articles found in the search. The first criterion (Criterion 1) eliminated articles that were not empirical, while the second (Criterion 2) eliminated those that did not report the effect size of the LP-business performance relationship using Pearson's correlation coefficients or other test statistics, such as Cohen's-d or F-statistics that can be converted to Pearson's correlation. Applying said criteria eliminated a total of 610 papers from the meta-analysis.

Stage 3. Final selection: After reading the articles in full, 29 articles were identified as studies consistent with the goal of our meta-analysis. Using the snowball approach, another four articles were identified and added from the citations and references in the aforementioned articles (see Negrão et al., 2017). A final screening during the coding process led to the elimination of three articles. Thus the search process yielded 30 articles in all.

[2] This is one of the fullest databases in the field of economics and business research. It includes thousands of full-text scientific journals, as well as dissertations, conference proceedings, and market reports, inter alia.

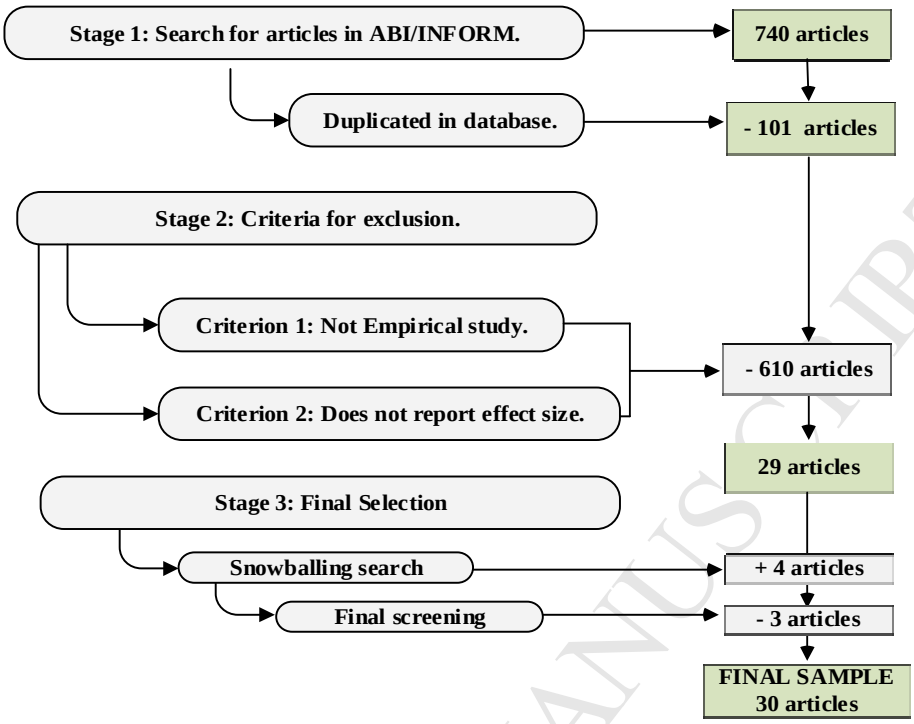


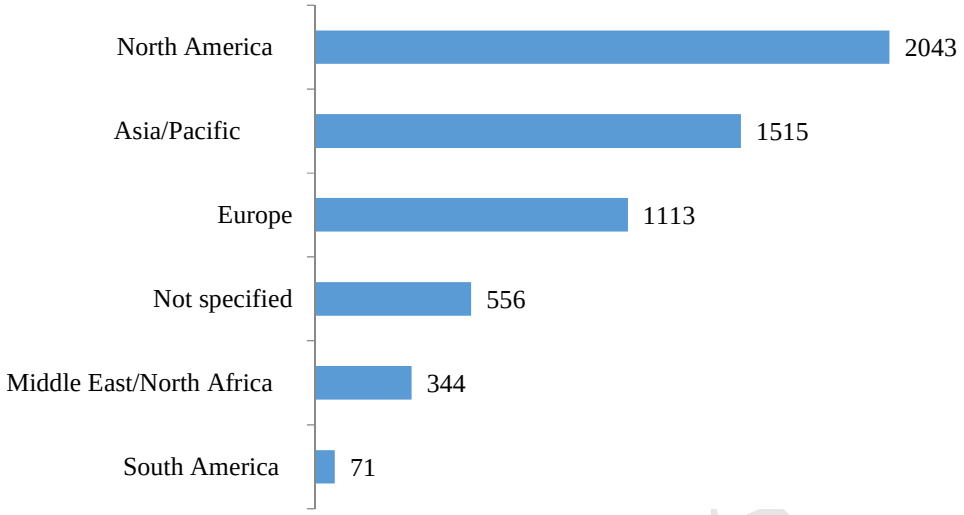
Fig. 2 Steps in sample gathering.

Several research studies in the meta-analysis field (Webb et al., 1981; Hunter and Schmidt, 2004; Mackelprang and Nair, 2010) state that the items used to measure individual lean practices and performance could be somewhat different across the studies, and this was taken into account in the article selection process. Therefore, careful analysis had to be carried out to determine whether these different measures conformed to the definitions used in this study.

The articles were also analysed to guarantee that the studies included in the sample were independent. Two special cases were identified: Fuentes-Fuentes et al. (2004) and Fuentes-Fuentes et al. (2006) use the same data set for different research questions and so were included as a single study. Likewise, another three articles by the same authors were omitted from a group of five articles as they were suspected of using the same, or almost the same, company sample. The criteria used to select the articles used in our study were sample size (the greater the size, the higher the statistical power) and whether the constructs used in the articles were consistent with the present study's definitions and operationalisations.

Four papers were identified as reporting partial information. An email request was sent to their authors in an effort to obtain the missing information. Unfortunately, none of the authors answered, and the papers were therefore excluded from the study. In Figure 2 these articles are counted among those discarded because of exclusion criterion 2.

The final study sample was eventually made up of twenty-nine studies (with 5,642 firms from Asia, Europe and America) (see Figure 3).



Note: 'Not specified' includes some North American and European firms

Fig. 3 Geographical distribution of the firms included in the sample.

This is a larger sample size than in other operations management meta-analyses (e.g., Gerwin and Barrowman, 2002; Nair, 2006; Mackelprang and Nair, 2010). The empirical papers included in the sample were published in a total of fifteen different journals, several of which are considered to be the most important in the areas of Operations Management and Accounting, according to Chan et al. (2009) and Hsieh and Chang (2009), respectively (see Table 2).

Table 2. Journals in which sample research studies were published.

Journal name	***Number of articles***	***Percentage***
Journal of Operations Management	*5*	17%
.Decision Sciences	*4*	13%
International Journal of Production Research	*4*	13%
International Journal of Operations and Production Management	*2*	7%
International Journal of Production Economics	*2*	7%
International Journal of Quality and Reliability Management	*2*	7%
Journal of Manufacturing Technology Management	*2*	7%
Omega	*2*	7%
Academy of Management Journal	*1*	3%
Industrial Management and Data System	*1*	3%
International Journal of Management Studies	*1*	3%
International Journal of Productivity and Quality Management	*1*	3%
Journal of Service Management	*1*	3%
Production and Operations Management	*1*	3%
Total Quality Management and Business Excellence	*1*	3%

3.3. Coding

An Excel spreadsheet was used for the coding process which had been designed with all the fields needed to calculate effects sizes and conduct any moderation analyses that might be required. Coded fields included: authors; year; sector under study; sample size; country; statistical analysis method; abstract; main study results; measurement scales used; reliability of scales, *inter alia*. One of the coded variables for subsequent treatment as a moderating factor was the type of economy of the country where the firms in the sample were located. Based on IMF (2016) statistics, countries were classified into two groups: (1) Advanced economies, and (2) Emerging Market/Developing Economies. Table 3 profiles the studies.

Table 3. Profile of studies

	n	*%*		*n*	*%*
Sector			*Country or region*		
Manufacturing	24	82.76	United States	11	37.93
Service	2	6.90	ASEAN[b]	6	20.69
Manufacturing + Service	3	10.34	Europe	3	10.34
Country classification			India	2	6.90
Advanced economies	17	58.62	Tunisia	1	3.45
EM&DE[a]	9	31.03	China and Hong Kong	1	3.45
Not specified	3	10.34	North America	1	3.45
Statistical methods			North America and Europe	1	3.45
SEM[c]	16	55.17	Iran and Malaysia	1	3.45
Correlation and Regression	10	34.48	Turkey	1	3.45
Path Analysis	3	10.34	Not specified	1	3.45

Notes: [a]Emerging Market & Developing Economies; [b]Association of Southeast Asian Nations; [c]Structural Equation Modelling.

In accordance with the meta-analysis of correlations technique, three essential pieces of information were taken from each study: sample size, reliability of dependent and independent variables, and correlation coefficients. In some cases, where the reliability was unavailable or could not be obtained from the authors, average reliability reported across all the studies was used as a substitute (Bamberger et al., 1999; Kinicki et al., 2002; Mackelprang and Nair, 2010). To consider interdependence among lean practices and dimensions, correlation coefficients have been taken between all possible pairs of lean practices and each of the lean practices and the performance measures.

There were also differences in the way that said studies measured performance indicators in the relationship with performance. Almost all the articles used perceptual scales and only two (Hofer et al., 2012 and Ghobakhloo and Hong, 2014) preferred to use the numerical values of the indicators.

Other differences found in prior studies were the analytical unit and the statistical method used for the analysis. In general, the majority of papers addressed the company level (Hofer et al., 2012). Research design was cross-sectional or correlational in the vast majority of cases, meaning that it was not possible to directly address causality in the LP–performance relationship. Regression and structural equation modelling (SEM) were the most used statistical methods of analysis (Das et al., 2000, Kaynak, 2003, Nahm et al., 2004, Avittathur and Swamidass, 2007, Agus, 2008, Hong et al., 2014, among others). A detailed description of the 30 articles is provided in Appendix A.

The coding process was carried out by one of the authors. To ensure reliability of the coding, a second author carried out parallel coding of all the studies. Level of agreement was 96.32% and discrepancies were resolved by discussion.

3.4. Statistical methods

The present research uses the Hunter and Schmidt (2004) procedure. The heuristic nature of this

approach overcomes the difficulties of the statistical power of significance tests when the number of studies is small (Gerwin and Barrowman, 2002). In addition, it considers several artefacts that may affect correlation. In this paper, corrections are made for any measurement errors in the variables of each correlation (Hunter & Schmidt, 2004).

The research was carried out in three stages. In the first stage, the relationship between aggregate level LP and aggregate level business performance (H1) was examined. The second stage considered the separate relationships between all the individual lean practices and business performance (H2 to H7). In both stages, the relationship was also separately examined with each of the performance metrics (a. financial performance, and b. market performance). The data used in the first and second stages are given in Appendix B. In the third stage, moderator analyses were carried out to explain the heterogeneity found in the previous relationships. Appendix C gives the data used in the third stage.

A simple mean was not used to estimate the correlation coefficient between the aggregated lean practices and each of the performance measures under consideration, as that would have assumed the sizes of the effects in each study to be independent. So, composite effect sizes were calculated for each study to consider the interdependencies among the practices. The formula proposed by Hunter and Schmidt (2004: 435) was used:

$$r = \frac{\sum r_{x_i y}}{\sqrt{n + n \cdot (n-1) \cdot \bar{r}_{x_i x_j}}}$$

where r is the composite correlation in the study; $r_{x_i y}$ is the coefficient correlation observed between the lean practice x_i and the performance measure y; n is the number of lean practices considered in the study, and y $\bar{r}_{x_i x_j}$ is the average off-diagonal correlation in the correlation matrix of the lean practices.

The various studies were weighted by sample size (N_i) and the correction factor for scale reliability (A_i), $W_i = N_i \cdot A_i^2$ to combine the correlationship coefficients. The correction factor was calculated as $A_i = \sqrt{\propto_{xx}} \cdot \sqrt{\propto_{yy}}$, with α_{xx} being the independent variable's reliability coefficient (Cronbach's alpha) and α_{yy} that of the dependent variable. Composite correlations in each of the studies (r) were corrected by measurement error $r' = r/A$. The formula proposed by (Hunter & Schmidt, 2004) was used to estimate each study's corrected sampling error variance (S_{ei}^2):

$$S_{ei}^2 = {(1 - \bar{r}^2)^2}\Big/{(N_{i-1}) \cdot A^2}.$$

RATIO1 and credibility intervals, i.e., intervals not affected by sample error variance (Hunter & Schmidt, 2004), were used to determine the significance and accuracy of the mean correlations obtained for each of the hypotheses. As well as variance of the corrected correlations ($S_{r'}^2$), weighted mean sampling error variance (S_e^2) was also calculated to obtain effect variance on the population (S_p^2) by difference. Credibility intervals were linked to the use of random effects models (Hunter & Schmidt, 2004). RATIO1 was calculated as RATIO1 = ${\bar{r}'}/{S_p}$ (the average corrected correlation divided by the estimate of population standard deviation). This ratio converts mean correlation into its standard normal equivalent or z score, which can be used to detect whether population correlation is significantly different from zero. If RATIO1 is greater than or equal to 2, it is reasonable to conclude that population correlation is greater than zero. Credibility Intervals were obtained as follows: $\text{Credibility Interval} = \bar{r}' \pm Z_{(\propto/2)} \cdot S_p$ (the critical value of z for 5% significance level in a two-tailed test is 1.96). In addition, the Cohen (1992) guidelines for effect size were followed in the present meta-analysis, with correlations of 0.10, 0.30 and 0.50, considered as small, medium and large, respectively.

RATIO2 = $S_e^2 / S_{r'}^2$ (the corrected estimate of the sample error variability, divided by the corrected estimate of the study correlation variability) was used to measure the existence of heterogeneity in the correlations. This ratio reports the amount of observed variance due to study imperfections by detecting moderation effects**.** If RATIO2 is greater than or equal to 0.75, it is reasonable to conclude that there is only one population correlation. However, if the ratio is below 0.75, then moderating factors may be affecting the relationship between the variables.

The procedure followed was similar to that of MacKelprang & Nair (2010) and Mackelprang et al. (2014), in which more detailed descriptions can be found, including all the calculation formulae.

In the third stage, several moderation analyses were performed. When the moderating variable was categorical, studies were grouped according to this distinctive feature. The above-described Hunter and Schmidt (2004) procedure calculations were made for each subgroup. If there are clear differences among the mean corrected correlations, and if the subgroups are homogenous according to the RATIO2 criterion, this proves that the moderating variable influences the results. The whole procedure was done for each of the moderating factors and for all possible combinations of these. The analytical procedure for continuous moderating variables involves a weighted regression of the effect sizes onto the predictor.

If heterogeneity is not explained, Hierarchical Cluster Analysis is used to group the cases. Meta-analysis enables the homogeneity of each subgroup to be assessed and the observation of differences among these with respect to mean corrected correlations. The studies included in each cluster are then examined in detail with the aim of finding common or similar characteristics, i.e., new moderating variables.

To conclude, robustness of results in each of the previous stages was analysed, especially in relation to the risk of publishing bias. For this a fundamentally calculation-based diagnosis of the 'fail-safe number' was carried out for each of the studied relationships. Said number enables the meta-analysis' robustness to excluded or missing studies to be evaluated (Card, 2012). This problem, sometimes known as the 'file drawer problem', which can also be considered as a missing data issue (Cooper, 2016), occurs when authors decline to send studies with statistically non-significant results to journals and also reflects the tendency of journals to reject any papers of this type or that replicate previous studies.

Rosenthal (1979) proposed a method to estimate the 'fail-safe number' that calculates the number of additional studies with a mean null result necessary to reduce combined significance to a desired level (usually 0.05). As the Rosenthal (1979) method is essentially based on significance and not effect size, Orwin (1983) proposed a method that enables the calculation of the number of additional studies required to reduce mean observed effect size to a minimum desired effect size. Both of these methods were criticized by L'Abbé et al. (1987), Rosenberg (2005) and Borenstein et al. (2009), basically for not including any specification of the weight or sample size of studies that are not published.

Bearing the above in mind, this study proposes that the 'fail-safe number' be calculated as the sample size or number of companies that an additional study should be included to reduce mean corrected correlation to a level of 0.10 (considered to be the minimum for a weak correlation according to the Cohen (1992) guidelines. This number is obtained by simulation analogous with L'Abbé et al. (1987). The additional study is considered to have a mean size effect equal to zero and dependent and independent variable scale reliabilities that are the same as the mean values obtained from the study sample.

4. Results

4.1 Main effects and heterogeneity

Table 4 gives the meta-analysis results. The table shows the number of studies (k), the overall sample size (N), the average correlation ($\bar{r}$), the average corrected correlation ($\bar{r}'$), RATIO1, RATIO2, and Fail safe N for each combined analysis of lean metrics and performance metrics.

Firstly, LP (aggregate lean practices) is positively correlated with BP (aggregate business performance) (RATIO1 = 2.230), so hypothesis H1 is supported. The mean corrected correlation value between these variables is 0.313 and the 95% credibility interval is [0.038-0.587]. As zero is not included in this interval, assuming that the effect size correlation has a normal distribution, then the probability of zero or below zero correlation is very small (barely 2.22%) and the correlation between aggregate lean practices and aggregate performance can be stated to be positive (Hunter and Schmidt, 2004). The effect size of the impact of LP on BP can be considered medium or moderate according to Cohen's effect size benchmarks (Cohen, 1992). The value of RATIO2 = 0.251 (below 0.75) indicates that there is not only one population correlation, i.e., the relationship between aggregate lean practices and aggregate performance is influenced by moderating factors.

The same procedure and heuristics are used in the second stage for hypotheses H2 to H7. The results of this stage are presented in Table 4.

Table 4. Overall meta-analysis results.

Hypotheses	**k**	**N**	$\bar{r}$	$\bar{r}'$	**Credibility Interval**		**RATIO1**	**RATIO2**	**Fail Safe N**
H1. ALP									
⇨ ABP	29	5 642	0.257	0.313	0.038	0.587	**2.230**	0.251	11 890
a. FP	16	3 074	0.259	0.309	-0.051	0.670	1.682	0.161	6 453
b. MP	15	3 434	0.200	0.249	0.014	0.484	**2.079**	0.302	5 012
H2. PC&I									
⇨ ABP	13	2 332	0.262	0.314	0.154	0.475	**3.840**	0.511	5 052
a. FP	8	1 541	0.283	0.341	-0.021	0.703	1.849	0.161	3 730
b. MP	7	1 372	0.262	0.327	0.245	0.410	**7.787**	**0.794**	3 145
H3. JIT-flow									
⇨ ABP	10	1 788	0.184	0.227	-0.040	0.494	1.666	0.303	2 285
a. FP	7	1 295	0.188	0.235	-0.143	0.612	1.217	0.173	1 724
b. MP	7	1 446	0.155	0.192	-0.013	0.398	1.833	0.391	1 342
H4. WfD									
⇨ ABP	15	2 911	0.207	0.254	0.091	0.416	**3.063**	0.504	4 399
a. FP	7	1 395	0.208	0.250	0.112	0.388	**3.558**	0.568	2 084
b. MP	6	1 604	0.154	0.196			∞^{**}	**1.000**	1 470
H5. MM									
⇨ ABP	3	518	0.293	0.351	-0.066	0.769	1.649	0.137	1 358
a. FP	2	370	0.330	0.393	0.069	0.717	**2.376**	0.196	1 149
b. MP	2	370	0.071	0.065	-0.234	0.363	0.424	0.274	-
H6. CF									
⇨ ABP	16	3 051	0.208	0.258	0.121	0.395	**3.691**	0.591	4 760
a. FP	7	1146	0.228	0.273	0.158	0.387	**4.669**	0.693	2 032
b. MP	5	1292	0.128	0.169	0.059	0.279	**3.006**	0.662	845
H7. SR									
⇨ ABP	18	3 085	0.192	0.232	-0.030	0.494	1.733	0.309	4 124
a. FP	10	1 801	0.134	0.164	-0.114	0.442	1.155	0.286	1 147
b. MP	10	2 056	0.153	0.185	-0.016	0.387	1.805	0.397	1 766

Notes: ALP: aggregate lean practices; PC&I: Process Control & Improvements; JIT-flow: Just-in-time Flow; WfD: Workforce Development; MM: Maintenance Management; CF: Customer Focus; SR: Supplier Relationship; ABP: Aggregate Business Performance; FP: Financial Performance; MP: Market Performance.

As can be observed in Table 4, only three of the analyses relating individual lean practices to business performance are significant: H2 (Process control and improvements), H4 (Workforce Development) and H6 (Customer focus). Size effect is greater for Process control and improvements ($\bar{r}$=0.314) and more limited and fairly similar in the cases of Customer Focus ($\bar{r}$=0.258) and Workforce Development ($\bar{r}$=0.254). In all three cases, RATIO2 indicates that there is heterogeneity.

However, when the separate relationships with the two performance measures are analysed, aggregate level LP are observed to have a positive influence on market performance ($\bar{r}$=0.203), but a null effect on financial performance cannot be ruled out. On the level of specific lean practices, three are detected to have a positive influence on financial performance (Workforce Development (H4a); Maintenance Management (H5a); and Customer Focus (H6a)). The same number of practices (three) has been detected to have a positive influence on business performance (Process Control & Improvement (H1b); Workforce Development (H4b); Customer Focus (H6b)). RATIO2 indicates the presence of heterogeneity in all the effects except in the cases of Workforce Development on market performance (H4b) and Process Control & Improvements on market performance (H2b). The results of this stage are presented in Table 4.

All the effects shown in Table 4 are positive, and 61.9% of mean corrected correlations (13 out of 21) range between 0.164 and 0.273, which, according to the Cohen classification, means that they are small effects; 33.3% (7 out of 21) are between 0.309 and 0.393, and can be considered moderate effects; and only one has a mean of 0.065, which can be considered insignificant or trivial.

4.2 Moderation analysis

The previous section shows that 19 of the 21 analysed effects in the hypotheses demonstrate heterogeneity. To explain this, partially at least, moderation analyses were carried out with three different variables: sector, time and the country's level of economic development. Only the last of these three factors had a moderating effect. For sector, a subgroup analysis was performed differentiating between studies of manufacturing companies and other sectors. As this analysis showed no appreciable difference between the two groups, the results are not given. Year of study publication was included in the model for the time factor. The estimation of the coefficient was almost null (β = 0.009, p = 0.202, 95% CI [-0.005, 0.023]). A subgroup analysis of the last of the three factors was done based on the economy of the country where companies were located and differentiating between two categories: (1) Advanced Economies, and (2) Emerging Market & Developing Economies. Analysis results are given in Table 5.

Due to a lack of data, results could not be obtained in four (4) of the 20 relationships in which heterogeneity was detected in the global meta-analysis. It is revealing that in the other 16 relationships (80%), subgroup mean corrected correlations were substantially different in all cases. According to the Cohen (1992) criterion, correlation effect sizes in 14 of the relationships were weak (in a range of 0.104-0.295) for the Advanced Economies subgroup and moderate for the Emerging Market & Developing Economies subgroup.

Homogeneity analysis (RATIO2) in Table 5 reveals that there continue to be moderating variables in the subgroups for some of the studied relationships. So, further analyses were carried out with year of publication, industrial sector (manufacturing only vs. others) and a combination of

this last factor and the country's economic classification. These new analyses did not yield any significant results, either.

Table 5. Subgroup analysis of Lean Practices effects on performance (moderator analysis)

Relationships	Groups	k	N	$\bar{r}$	$\bar{r}'$	Credibility Interval	RATIO1	RATIO2	Fail Safe N
ALP ➔AFP	AE	17	3 621	0.236	0.282	0.045 0.520	**2.328**	0.288	6 559
	EM&DE	9	1 168	0.392	0.463	0.242 0.683	**4.111**	**0.783**	4 399
ALP ➔FP	AE	8	1 893	0.168	0.203	0.017 0.389	**2.145**	0.386	1 929
	EM&DE	6	899	0.453	0.536	0.230 0.842	**3.432**	0.199	4 009
ALP ➔MP	AE	8	1 985	0.169	0.205	0.069 0.342	**2.943**	0.532	2 027
	EM&DE	4	596	0.353	0.434	0.302 0.566	**6.453**	0.640	2 088
PC&I ➔AFP	AE	6	1 255	0.200	0.242		∞	**1.000**	1 805
	EM&DE	5	795	0.384	0.457		∞	**1.000**	2 879
PC&I➔FP	AE	2	579	0.145	0.181	-0.127 0.489	1.150	0.167	466
	EM&DE	4	680	0.445	0.527	0.413 0.641	**9.042**	0.614	2 962
PC&I➔MP	AE	2	520	0.200	0.258		∞	**1.000**	807
	EM&DE	3	570	0.348	0.425		∞	**1.000**	1 954
JIT-flow ➔AFP	AE	6	1 192	0.119	0.146	-0.041 0.334	1.529	0.453	548
	EM&DE	4	596	0.313	0.386		∞	**1.000**	1 761
JIT-flow➔FP	AE	3	699	0.047	0.060		∞	**1.000**	-
	EM&DE	4	596	0.353	0.430	0.202 0.657	**3.701**	0.366	2 019
JIT-flow➔MP	AE	3	850	0.070	0.087		∞	**1.000**	-
	EM&DE	4	596	0.277	0.347		∞	**1.000**	1 539
WfD ➔AFP	AE	6	1 255	0.217	0.252	0.083 0.421	**2.920**	0.444	1 938
	EM&DE	6	803	0.288	0.338	0.267 0.409	**9.285**	**0.874**	1 966
WfD ➔FP	AE	2	579	0.153	0.184		∞	**1.000**	485
	EM&DE	3	534	0.322	0.374		∞	**1.000**	1 451
WfD ➔MP	AE	2	520	0.195	0.234		∞	**1.000**	680
	EM&DE	1	231			Insufficient data for analysis			-
MM ➔AFP	AE	1	148			Insufficient data for analysis			-
	EM&DE	2	370	0.200	0.231	-0.088 0.550	1.418	0.230	523
MM ➔FP	AE	0							-
	EM&DE	2	370	0.330	0.393	0.069 0.717	**2.376**	0.196	1 149
MM ➔MP	AE	0							-
	EM&DE	2	370	0.071	0.065	-0.234 0.363	0.424	0.274	-
CF ➔AFP	AE	7	1 395	0.252	0.295		∞	**1.000**	2 786
	EM&DE	6	803	0.276	0.326		∞	**1.000**	1 850
CF ➔FP	AE	2	330	0.209	0.241		∞	**1.000**	513
	EM&DE	3	534	0.309	0.363		∞	**1.000**	1 407
CF ➔MP	AE	1	208			Insufficient data for analysis			-
	EM&DE	1	231			Insufficient data for analysis			-
SR ➔AFP	AE	11	2 351	0.160	0.193	0.028 0.359	**2.286**	0.472	2 187
	EM&DE	5	452	0.402	0.502	0.280 0.725	**4.426**	0.492	1 837
SR ➔FP	AE	5	1 244	0.085	0.104		∞	**1.000**	53
	EM&DE	3	275	0.387	0.478	0.073 0.883	**2.316**	0.226	1 037
SR ➔MP	AE	6	1 609	0.134	0.164	0.019 0.309	**2.219**	0.487	998
	EM&DE	2	165	0.347	0.480	0.217 0.744	**3.574**	0.512	574

Notes: AE, Advanced Economies; EM&DE, Emerging Market & Developing Economies; **All cases with RATIO1 = ∞ caused a negative variance in population correlation (S_p^2); Hunter and Schmidt (2004: 411) refer to this problem as second-order sampling error. S_p^2 has been treated as if it were equal to zero (Hunter and Schmidt, 2004: 89) and so RATIO2 is considered to be 1 or 100%.

A Hierarchical Cluster Analysis (IBM SPSS Statistics 22.0) was done in an attempt to explain the unexplained heterogeneity in the aggregate level LP-BP relationship in developed countries. Cases (studies) were grouped using corrected correlation as the grouping variable. The linkage criterion used was Average Linkage Between Groups. The resulting dendrogram in Figure 4 shows the grouping for the specific Aggregate LP and Aggregate business performance relationship in Advanced Economies. The Euclidean Squared Distance was used as the measure to express (dis)similarity between pairs of studies.

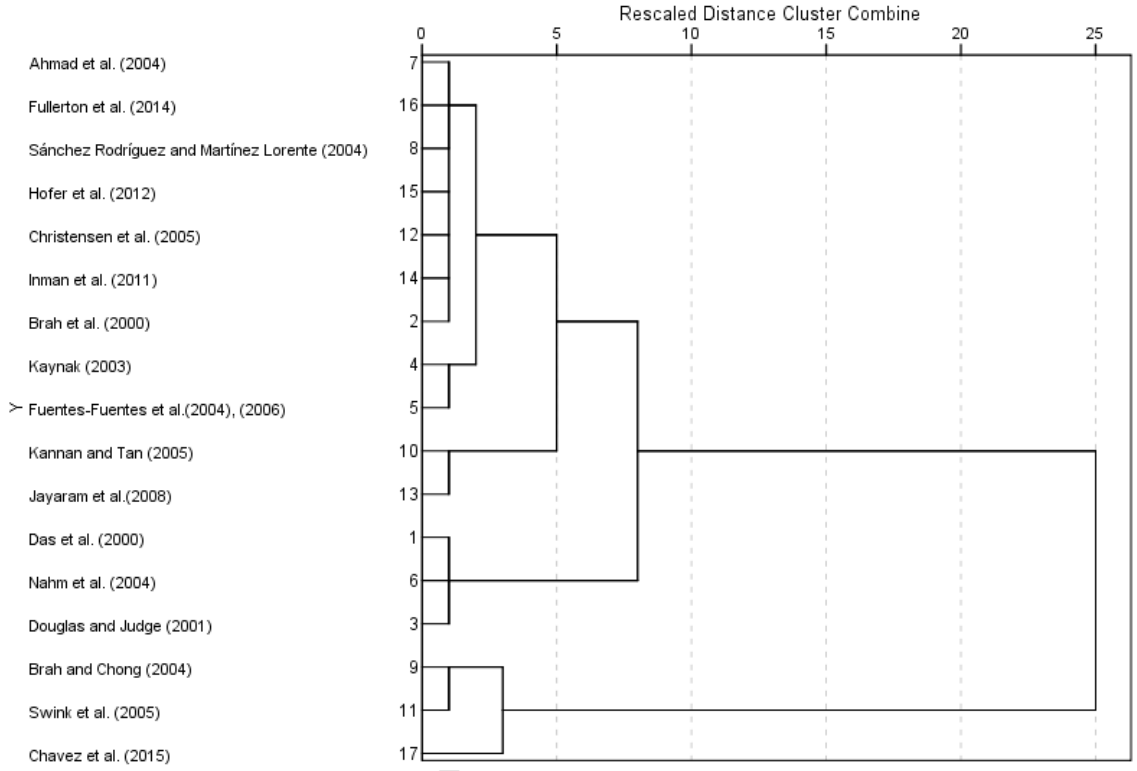


Fig. 4. Dendrogram (using Average Linkage Between groups) obtained following Hierarchical Cluster Analysis.

Setting a cut-off point on a rescaled distance of 5 creates three subgroups of studies. A meta-analysis was done within the three subgroups to verify cluster selections. Significant differences were observed between mean corrected correlations in all three cases (0.202; 0.388 and 0.569). The heterogeneity of each subgroup was also assessed and yielded RATIO2 values of 0.898, 1.000 and 1.000. A new detailed search was then done of studies in the three subgroups to find any similarities or differences among them. According to the resulting information, nothing in common was found to exist that could be taken as a contextual or moderating variable. Therefore, the identified variability could not be explained.

4.3. Publication bias

The robustness of the results was analysed with the fail safe number to address the issue of publication bias. As previously established, simulation was used to calculate this number. More specifically, a macro was created in Excel 2013 (v15.0). As can be seen in Tables 4 and 5, the 'fail-safe N' varied between 53 and 11,890. Given the meticulous search carried out to obtain the

sample, many of these values can be considered to be significantly high, which demonstrates the robustness of the obtained results. It is worth highlighting that the 'fail-safe N' obtained in the LP (Aggregate lean practices) - Aggregate business performance relationship, where the sample size considered in the meta-analysis (N) was 5,642 companies, was 11,890 companies.

However, the 'Fail-safe N' of 845 in the Customer Focus-Market performance relationship can be considered low, as the size of the sample in the meta-analysis was only 1,292 companies. The Fail-safe N for some individual practices in Table 5 are also quite low. For this reason, future studies on these relationships by type of economy are still needed to reduce publication bias and guarantee the real effects.

5 Discussion

This section provides responses to the proposed research questions by interpreting the results. To begin with, Table 6 presents a summary of the results obtained for the hypotheses proposed in Section 2.

Table 6. Hypothesis testing.

Hypothesis	Main hypothesis …→ business performance	Sub hypotheses …→ a) financial performance	…→ b) market performance
H1: Lean Production → …	Yes	No	Yes
H2: Process Control & Improvement → …	Yes	No	Yes
H3: JIT-Flow → …	No	No	No
H4: Workforce Development → …	Yes	Yes	Yes
H5: Maintenance Management → …	No	Yes	No
H6: Customer Focus → …	Yes	Yes	Yes
H7: Supplier Relationships → …	No	No	No

5.1. Is LP positively correlated with business performance?

This study provides evidence of a positive correlation between aggregate LP and aggregate business performance, H1. This result is widely supported by several papers considered in the sample (Kaynak, 2003, (Ahmad et al., 2004; Fullerton & Wempe, 2009; Hofer, Eroglu, & Rossiter Hofer, 2012; Kaynak, 2003) and suggests that firms implementing LP can achieve positive business performance. The mean effect of LP on business performance barely reaches a moderate or medium level ($\bar{r}$ = 0.31) and the wide variation at a 95% credibility interval shows that the impact can vary widely: from 0.59 (which can be considered a large effect) to less than 0.04, which can be considered trivial. It should be borne in mind that r = 0.10 would indicate that only 1% performance variability is associated with LP practices. The mean effect observed is greater than that found by Mackelprang and Nair (2010) in the JIT–operational performance relationship (0.25), although the smaller 95% credibility interval shows that greater accuracy is achieved in their case. As already stated, it is logical that the LP effect should be more reliably felt on operational performance measures, as these are more directly linked with the latter's results. It is also true that Mackelprang and Nair (2010) did not correct the mean effect with the inter-correlations among the practices considered, as has been done in this study.

However, the relationship is not always positive when financial performance is considered separately. In this case, the result of this study is in line with Losonci and Demeter (2013) and the Camacho-Miñano et al. (2013) review. The present study has shown that, despite mean correlation being positive and moderate ($\bar{r}$ = 0.31), it is subject to high variability, which means that the null effect cannot be ruled out. In a way, it is logical that this high variability should exist, as financial results are influenced by many variables. The operations area may not be directly responsible for these variables, which might be related to other areas of the company, such as the financial area

(interest rate, exchange rate) (Klingenberg et al., 2013), and some may be external to the company and outside its control altogether. In other respects, despite being smaller in size ($\bar{r}$ = 0.25), the LP–market performance relationship, is clearly positive, due to less variability and a narrower credibility interval.

5.2. Which Lean Practices have a stronger impact on business performance?

Several interesting findings have been revealed regarding the relationships between individual lean practices and the two performance metrics. Firstly, all of the relationships between the considered practices and business performance are positive, which is in line with theory (e.g., Kaynak, 2003; Lakhal et al., 2006, Laosirihongthong et al., 2013, Akgün et al., 2014). However, only three are statistically significant: Process Control and Improvement (H2), Workforce Development (H4) and Customer Focus (H6). Of these, PC&I has the greatest effect (0.31), although its credibility interval indicates that there is a fair amount of variability among companies. In contrast, CF has a slightly lower (0.26) but more consistent effect. The effect of WfD is similar to the latter (0.25), but much more variable. The other three practices, JIT, MM and SR, all have effects that are similar in size to the above (0.23, 0.35 and 0.23, respectively), but they are not always positive due to their greater variability (especially high in the case of MM, which also presents the highest mean effect). It may be that JIT flow (H3), MM implementation (H5) and lean relationships with suppliers (H7) do not offer advantages to firms in some sectors. For example, it is apparent that not all sectors have production processes that are capable of adapting to the continuous flow required by JIT. Productive maintenance is not a practice that can be applied and benefited from by all types of company, either, with service companies an obvious case in point. In light of the results, it would also seem that the supplier relationships that LP advocates –few suppliers, long-term relationships and frequent deliveries- cannot be universally recommended to all companies. In contrast, Process Control and Improvement, Workforce Development and Customer Focus are all practices with much more generic applications.

When the effects of these practices on financial performance are analysed individually (hypotheses a), there are two differences from the above. To understand these differences, it has to be borne in mind that some studies in the present research were included in the sample for the aggregate level analysis but omitted from the sample for the individual performance level analysis, as the results of some studies had only been reported at aggregate level. On the one hand, the association between PC&I and financial performance is not always positive. This means that better control and process improvement do not always impact the firm's financial results. However, a positive effect of a moderate size (0.39) emerges between MM and financial performance. Mackelprang and Nair (2010) also found a strong association between preventive maintenance and cost. It would therefore seem that good maintenance management can generate financial rewards for companies that work according to the principles of JIT, probably on account of the reductions in costs that MM produces.

With respect to market performance, there were no discrepancies from the results for aggregate level business, although the smaller effects of WfD and CF on market performance can be highlighted.

5.3. Is this relationship homogenous or are there any moderators involved?

Results indicated that almost all the relationships between LP and performance are influenced by moderating factors, except for the relationship between PC&I and market performance (H2) and WfD and market performance (H4). This means that contextual factors may influence the magnitude of these relationships and that there is probably no single, common effect in the population. Analyses were conducted with different moderating variables to try and explain this heterogeneity. Results suggested that neither the sector (manufacturing vs. services) nor the study

publication date are relevant explanatory sources of heterogeneity. However, type of country (advanced vs. developing) shows differences in the effect sizes of LP and its practices on performance. Emerging economies obtained greater effects on performance than advanced economies in all the relationships that it was possible to analyse (15; sufficient data were not available for the other three) using this moderating variable (Table 5). This may be due to LP implementation having been more recent in said countries and there are greater advantages during the initial years (Yang et al., 2011). It could also simply be associated with these countries' greater growth during the considered period (World Economic Outlook Database, October 2016) being reflected by the superior performance of their firms over countries with advanced economies.

However, within these two subgroups (advanced vs. developing countries) there continues to be unexplained heterogeneity for some of the analysed effects (specifically, in 18 out of a total of 36). In addition, the cluster analysis performed for the effect of LP on ABP in the Advanced Economies group indicated that there were two different effects in the analysed studies, but it was not possible to determine what the underlying moderating variable (or variables) was.

6 Conclusions

This research presents the results of a meta-analytic study of the relationship between LP and Performance by condensing research published in high impact journals from 2000 to 2016. The results indicate that when considered as a whole, LP positively impacts business performance on an aggregate level, as well as market performance individually, but not financial performance. However, these effects are highly variable. This high variability therefore offers great opportunities for further research into the potential moderating variables that may affect these relationships. Given LP's importance in the business and academic worlds, the present study has implications for theory, for future research and for business practice, which will all be examined below. The study was also scrutinised to determine whether the findings can be generalised and what the limitations are. Some future lines of research are also proposed.

6.1. Implications for theory

One of the clear objectives of any meta-analysis is to organise and synthesise previous research as a necessary step for the advancement of scientific knowledge of a phenomenon or object of study (Card, 2013). From this point-of-view, the present study has major implications for the Lean research community. This meta-analysis complements that done by Mackelprang and Nair (2010), which analysed the LP-operating performance relationship in a study of LP's impact on business performance, measured via its financial and market dimensions.

This study sheds light on inconsistencies in prior research into the LP–business performance (financial and market) relationship; the analysed studies present correlations from -0.01 to 0.53. Our findings indicate that the impact of LP on BP is $\bar{r} = 0.31$ (95% CI: 0.06. 0.46). One possible contribution that future research could make would be for this value to be used in the null hypothesis instead of the traditional value of zero, which presupposes that no relationship exists between LP and BP.

In other respects, when a distinction is made between the two considered performance dimensions, the obtained result is that the impact of LP on financial performance is not statistically significant; however, $\bar{r} = 0.31$, so the variability of the effect is very high. The reason for this could be the different ways that financial performance has been measured (ROI, ROE, ROS, revenue growth, etc.); despite these all being universal accounting indicators, it has been observed in the literature that the same financial ratios have been calculated in different ways. In addition to this, financial variables are calculated *in toto*, as a whole, whereas LP is only applied on the manufacturing plant level (Escobar et al., 2012). The above might also be a reflection of the fact that financial performance depends on many other factors that are unrelated to LP implementation as such. As Losonci and Demeter (2013) and Klingenberg et al. (2013) stress, many factors that

influence the business performance of lean producers are outside of the scope of Operations Management. However, the present study confirms that LP has a significant impact on market performance and that the effect is, moreover, less variable or heterogeneous.

Individual analyses of LP practices also have interesting implications for theory. Three of these, those that are related to quality (PC&I), employees (WfD) and customers (CF), are the most important determinants of performance. In contrast, those related to production flow (JIT-flow), maintenance (MM) and suppliers (SR) have no significant impact on performance. However, the number of studies and the size of the grouped sample show that less attention has been given to MM than to other practices.

Finally, the heterogeneity analysis shows that most of the analysed relationships are subject to great variability. The present study has demonstrated that neither time, nor sector (manufacturing vs. services) are factors that help to explain this heterogeneity and only country level of development provides a partial explanation. As such, further empirical studies are required that focus on analysing other contextual factors that might contribute to better understanding LP's impact on BP. Such studies would be especially useful in the case of the three practices that do not have a significant impact on performance. Section 6.3, which presents a discussion of the study's limitations, also points to some further research implications.

6.2. Implications for business practice

The results of this study may be of interest to firms, as they show that LP implementation is positively related to business performance and that the effect is medium in size but rather variable. This positive relationship is also clearly shown to exist in the case of market performance. This can help operations managers convince their colleagues in other areas, such as the business area and senior management, of the advantages to implementing LP over and above the operational benefits. However, the impact on financial performance is rather variable, and the possible lack of any effect at all cannot be ignored. Consequently, we believe that justifying LP implementation in a company based solely on traditional metrics and financial indicators should be avoided. Other dimensions on which LP has been empirically demonstrated to have a positive effect, particularly operating performance (Mackelprang and Nair, 2010) and market performance, should be taken into account in the evaluation. LP may also have a positive effect on other major performance dimensions, employees and the future, although there is still very little empirical evidence in this regard.

In other respects, the results of the individual analyses that have been done of LP practices can guide companies as to which they need to reinforce or prioritise for their own particular objectives. The literature also provides some clues as to the applicability of the various practices or tools depending on companies' contextual factors. However, this is a field in which more empirical studies are required that might help companies to tailor their Lean implementations to their own needs and circumstances.

6.3. Limitations and future research

As is the case with any meta-analytic study, the generalisation of this paper's findings is determined by a variety of factors, but, in particular, by the representativeness of the sample of studies included in this preliminary analysis on the one hand, and of the sample of companies, on the other. With respect to the first of these two issues, an effort has been made to include all the studies that are relevant for this research, but access was not made available to any unpublished studies. However, the calculation of the Failsafe N enabled risk of publication bias, or file drawer bias to give it its other name, to be assessed, and the obtained results were concluded to be very robust.

With respect to the representativeness of the sample of companies analysed by the studies included in this meta-analysis, it can be observed that there is a greater percentage of studies on manufacturing firms than service companies. Given that LP initially emerged in manufacturing and

that this is the sector where it is most implemented, this lack of balance does not generate a risk of bias. Nonetheless, it does show that there is a need for further research into the impact of LP in the services sector. Also, the geographical distribution of the studies shows that studies of firms in the United States (37.93%) clearly predominate, and more studies in other countries are needed, especially Japan, Korea and Latin America, for which there are none in the sample.

None of the studies are longitudinal. Studies of this type would enable an analysis of causality in the LP implementation-performance relationship and its possible evolution over time. Such studies are difficult to conduct, but would represent a significant step forward in our understanding of the impact of LP implementation.

The existence of unexplained heterogeneity in some of the analysed effects, such as the effect of LP on aggregate performance in advanced economies, for example, are issues that need to be investigated. The lack of detail in the studies means that it is impossible to analyse some typical potential moderating factors, such as firm size and specific sector, rather than just the distinction between manufacturing and services. Future studies should explore these contextual factors, as well as the underlying causes of the differences between advanced and developing countries.

One major issue is the way that the two meta-analysis variables –in our case, LP and BP- are measured. In the case of LP implementation, this has been done in this study by measuring the main LP practices. As Liker (2004) clearly states, applying just some of the practices does not mean that the company has converted to Lean. LP requires more than this: it is a holistic approach that demands an all-round strategy, commitment and cultural change, both by management and the workforce. One important line of future research would have to be directed at fine tuning more precise and more complete instruments that achieve a high degree of consensus in the measurement of the degree of lean attained by companies for use in future empirical studies.

This paper has considered the influence that inter-dependencies among lean production (LP) dimensions have on the relationship between LP and business and market performance. This can be considered an additional contribution in relation to previous (meta-analysis based) literature on the relationship between lean practices and firm performance. However, future empirical research needs to be conducted to examine the effect of combining different types of lean practice bundles on several performance measures.

Lastly, two important dimensions of business performance have been considered in this study: financial and market. The LP-operating performance relationship had already been studied previously in a meta-analysis (Mackelprang and Nair, 2010). Other business performance dimensions remain to be analysed in relation to Lean application (Bhasin, 2008), such as those related to employees and preparation for the future. However, to date there has been very limited research into LP's impact on these two dimensions of performance. It would also be interesting to analyse any relationships that might exist within the LP framework, such as the possible mediating role of operating performance in the relationship between LP and the other performance dimensions, which is already the subject of some studies (Nawanir et al., 2013; Losonci and Demeter, 2013; Fullerton and Wempe, 2009). Finally, future studies could mitigate the bias of the different levels that exist between the application of LP and the calculation of FP. One last proposed future line of research is that, when analysing this relationship, samples are differentiated by unit of analysis - companies/plants: (1) cost-centre or (2) investment/profit centre.

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Appendix A. Summary of articles used for meta-analysis

Paper	Sample	Method	Lean Practices	Performance outcome	Key findings
Das et al. (2000)	290 manufacturing companies from 14 industries located in the United States	Structural Equation Modelling	Quality practices (TQM) 1. Supply chain management practices 2. Quality resources & evaluation 3. Quality training 4. Customer commitment	1. Return on Assets 2. Market Share of Company 3. Market Share increase	TQM practices have a significant positive relationship with financial performance
Brah et al. (2000)	176 companies from the Singapore services sector	Correlation analysis	TQM practices 1. Customer focus 2. Employee involvement 3. Employee training 4. Employee empowerment 5. Supplier quality management 6. Process improvement 7. Quality improvement rewards	Financial performance 1. Overall financial performance 2. Return on assets (ROA) 3. Revenue growth 4. Return on sales (ROS) 5. Market share	TQM as a whole does show a significant positive correlation with financial performance
Curkovic et al. (2000)	57 independently owned first-tier suppliers to General Motors, Ford, and Chrysler.	Correlation analysis	Quality-related action programs 1. Employee Empowerment 2. Cross-Functional Quality Teams 3. Quality Training 4. Statistical Process Control 5. Continuous Improvement 6. Closer Customer Relationships 7. Supplier Development	Financial performance 1. Pre-Tax ROA 2. After-Tax ROA 3. ROI 4. Growth in ROI Market performance 5. Market Share 6. Growth in Market Share	Only 13 of the 42 correlation coefficients are significant. It stands out that Statistical Process Control and Quality Training are not related to any of the performance measures. However, Continuous Improvement shows a significant relationship with all performance measures except Growth in Market Share.
Douglas and Judge (2001)	229 respondents from US hospitals	Hierarchical Regression	1. Emphasis on TQM-oriented training 2. Customer driven 3. Continuous improvement 4. Total quality methods	Perceived financial performance 1. Growth in earnings 2. Growth in revenue 3. Changes in market share 4. Return on assets 5. Long-term profitability level	TQM practices are significantly related to perceived financial performance (for the complete model $\beta = 0.26$; $p < 0.01$)
Kaynak (2003)	214 firms located in the United States. Manufacturing industries (SIC 20-39) and Service industries.	Structural Equation Modelling	TQM practices 1. Training 2. Employee relations 3. Supplier quality management 4. Process management	Financial and Market performance 1. Sales growth 2. Market share 3. Market share growth	TQM practices have a significant positive relationship with financial and market performance

Paper	Sample	Method	Lean Practices	Performance outcome	Key findings
Fuentes-Fuentes et al. (2004, 2006)	273 Spanish firms operating in a competitive environment. (manufacturing and services sectors)	Structural Equation Modelling	TQM dimensions 1. Internal/external cooperation 2. Customer focus 3. Continuous improvement 4. Process management 5. Employee focus	Financial performance 1. Growth in profits 2. Profitability growth	All TQM dimensions have a significant effect on financial performance, with exception of process management.
Nahm et al. (2004)	224 manufacturing firms from four industries (SIC codes within range 34-37) (USA)	Structural Equation Modelling	Time-based manufacturing 1. Re-engineering setup 2. Cellular manufacturing 3. Quality improvement efforts 4. Preventive maintenance 5. Pull production 6. Customer orientation 7. Integration with suppliers	1. Sales growth 2. Return on investment (ROI) 3. Market share gain 4. Overall competitive position	Time-based manufacturing practices have a significant impact on performance.
Ahmad et al. (2004)	86 firms located in the United States (manufacturing sector)	Path Analysis Method	JIT elements 1. Production Strategy: (Setup time reduction, In-house lot sizes, Group technology, Cross-training, Preventive maintenance, Uniform flow loading, Statistical process control, Focus factory, Employee involvement, Employee empowerment, Yidoka, Improved performance measurement, Work team) 2. Vendor/Supplier Strategy (Vendor lot sizes, Reduction of number of suppliers, Vendor lead time reduction, Quality certification of suppliers, Kanban, Long-term supplier agreement, Supplier development program) 3. EDI (EDI with suppliers, EDI with distributors)	Financial performance 1. Operating profits 2. Profits to sales ratio 3. Cash flow from operations 4. Return on investment Growth performance 1. Sales growth rate 2. Market share	Significant total effects of product strategy and vendor/supplier strategy on financial and growth performance. The emphasis given to EDI had no significant direct or indirect effect on managers' perceptions of performance indicators.
Sánchez Rodríguez and Martínez Lorente (2004)	306 of the largest manufacturing firms in Spain	Correlation analysis	Quality management practices 1. Purchasing management committed to total quality 2. Coordination with other functional areas in the company to improve quality. 3. Empowerment, training, teamwork, performance evaluation, and reward and recognition-based employee management 4. Establishment of cooperative relationships with suppliers and enhancement of suppliers' capabilities to meet buyers' requirements. 5. Effective evaluation and monitoring of customer satisfaction levels, purchasing and supplier quality performance.	Return on assets (ROA) Return on sales (ROS) Market share	All quality management practices in purchasing except benchmarking significantly and positively correlated with market share. Return on assets significantly correlated with management commitment, coordination and people management constructs, whereas, return on sales only significantly correlated with the management commitment construct.
Brah and Chong (2004)	148 firms in Singapore (80%	Correlation Analysis	Specific aspects of TPM implementation	Financial and Market performance	Significant positive correlation between TPM

Paper	Sample	Method	Lean Practices	Performance outcome	Key findings
	manufacturing firms and 20% service firms)			1. Profitability 2. Market share 3. Sales 4. Return of capital	and performance
Yeung et al. (2005)	225 electronics firms in Hong Kong and mainland China (manufacturing sector)	Path Analysis Method	1. Learning and teamwork 2. Employee Management System 3. Customer Focus 4. Supplier Management 5. Process Control and Improvement	Market Performance 1. Sales Volume 2. Profit Margins 3. Market Share Financial performance 1. Return on Investment (ROI) 2. Overall Profitability	Employee Management System, Supplier Management, and Process Control and Improvement the most influential factors for market and financial performance.
Kannan and Tan (2005)	556 senior operations and materials managers in North America and Europe. (manufacturing sector)	Correlation analysis	JIT elements 1. Material flow 2. Commitment to JIT 3. Supply management TQM elements 1. Strategic commitment to quality 2. Supplier capability SCM elements 1. Supply chain integration 2. Supply chain coordination 3. Supply chain development 4. Information sharing	1. Return on assets (ROA) 2. Market share 3. Competitiveness	JIT, TQM and SCM failed to correlate significantly with financial and market performance.
Swink et al. (2005)	57 North American manufacturing plants	Hierarchical moderated regression analysis	1. Supplier relationship 2. Product-process development 3. JIT flow 4. Workforce development 5. Process quality management	Market performance 1. Profitability 2. Market share 3. Unit growth rate in sales	Correlation coefficients positive and significant at the 0.05 level for all relationships with the exception of the coefficient for supplier relationship management.
Christensen et al. (2005)	208 US manufacturing firms (two-digit SIC codes within 20-39 range)	Structural Equation Modelling	JIT-Strategy 1. JIT purchasing 2. JIT production 3. JIT sales Customer focus Supplier relationship	Market performance 1. Market share growth 2. Sales growth	Customer focus had a significant and positive relationship with market performance. JIT-Strategy and Supplier relationships failed to correlate significantly with market performance.
Lakhal et al. (2006)	92 Tunisian companies from the plastics transformation sector	Path Analysis Method	Quality Management practices 1. Employee training 2. Employee participation 3. Customer focus	Financial performance 1. Return on investments (ROI) 2. Return on assets (ROA) 3. Sales growth	Positive impact of quality management practices on financial performance
Avittathur and	26 U.S.	Regression	Use JIT criteria to select small suppliers	Financial performance	Relationship between lean

Paper	Sample	Method	Lean Practices	Performance outcome	Key findings
Swamidass (2007)	manufacturing plants in India that come under Standard Industrial Classifications (SIC) codes 34-38		JIT practices of Small Suppliers Automated supply practices of small suppliers Plant flexibility	1. Sales growth 2. Profitability	practices and financial performance not significant.
Jayaram et al.(2008)	57 U.S. firms in the automotive supplier industry. (manufacturing sector)	Structural Equation Modelling	Relationship building 1. Closer customer relationships 2. Supplier partnering 3. Supplier development Lean manufacturing 4. Just-in-time manufacturing 5. Setup time reduction 6. Cellular manufacturing	Financial performance 1. Pre-tax return on assets. 2. Return on investment. 3. Return on sales	Relationship between lean manufacturing and financial performance not significant.
Agus (2008)	110 manufacturing companies in the electronics and electrical industries in Malaysia	Correlation and multiple regression analysis	TQM practices 1. Customer focus 2. Supplier relations 3. Training 4. Employee focus 5. Zero defects 6. Process improvement	Profitability	Statistical positive effect of QM practices on profitability. Profitability higher for companies with high implementation of QM practices.
Inman et al. (2011)	96 manufacturing organisations from seventeen specific industries located in the US	Structural Equation Modelling	1. JIT-purchasing 2. JIT-production	Financial performance 1. Return on investment 2. Profit 3. Profit growth 4. Return on sales Market performance 1. Market share 2. Sales growth 3. Sales volume growth	Positive and significant correlation coefficients at 0.05 level for all relationships with the exception of JIT-purchasing and financial performance.
Agus and Hajinoor (2012)	200 companies from non-food manufacturing industries on the Malaysian peninsula	Structural Equation Modelling	1. Setup time reduction 2. Continuous improvement program 3. Pull production system 4. Shorter lead time 5. Small lot sizes	1. Profitability 2. Return on sales (ROS) 3. Return on assets (ROA) 4. Market share	Lean production practices positively associated with financial and market performance except for Setup time reduction practice
Hofer et al. (2012)	229 APICS (Association for Operations Management) members in the manufacturing sector (USA)	Structural Equation Modelling	External lean practices 1. Supplier feedback 2. Supplier JIT 3. Supplier development Internal lean practices 1. Pull system 2. Continuous flow 3. Setup time reduction	1. Sales growth 2. Return on sales (ROS) 3. Net sales	Positive but insignificant correlations of internal lean practices and external lean practices with ROS and statistically significant positive correlations with sales growth.

Paper	Sample	Method	Lean Practices	Performance outcome	Key findings
			4. Statistical process control 5. Employee involvement 6. Total productive maintenance		
Nawanir et al. (2013) (de 1 a 5)	139 large Indonesian manufacturing companies	Structural Equation Modelling	1. Cellular layouts 2. Pull system 3. Small lot production 4. Quick setup 5. Uniform production level 6. Quality at source 7. TPM 8. Supplier networks	1. Profitability 2. Sales	Lean manufacturing practices positively associated with financial performance
Laosirihongthong et al. (2013)	115 automotive parts/components manufacturing companies from five ASEAN countries (Indonesia, Malaysia, Philippines, Thailand and Vietnam)	Structural Equation Modelling	TQM practices 1. Customer focus 2. Supplier relationship 3. People management 4. Process management	1. Sales growth 2. Market growth 3. Market share 4. Profitability	All TQM practices positive and significantly correlated with performance
Fullerton et al. (2014)	244 U.S. manufacturing firms	Structural Equation Modelling	1. Standardisation 2. Manufacturing cells 3. Reduced setup times 4. Kanban system 5. One-piece flow 6. Reduced lot sizes 7. Reduced buffer inventories 8. 5S 9. Kaizen (continuous improvement)	1. Net sales 2. Market share 3. Return on assets (ROA) 4. Overall firm profitability	Implementation of lean manufacturing practices significantly correlated with performance.
Ghobakhloo and Hong (2014)	231 leading Iranian and Malaysian auto-part manufacturers	Structural Equation Modelling	1. Just-in-time 2. Quality Management 3. Maintenance Management 4. Customer Involvement 5. Human Resource Management	Financial performance 1. Return on assets (ROA) 2. Return on investment (ROI) 3. Return on sales (ROS) Market performance 1. Products: market share 2. Products: sales 3. Product delivery cycle time	All lean bundles significantly correlated with financial performance. Only just-in-time and quality management significantly correlated with market performance.
Akgün et al. (2014)	193 firms operating according to International Standards Organisation and	Structural Equation Modelling	TQM elements 1. Customer focus 2. People management	1. Return on investment (ROI) 2. Gross margin (Profitability/total sales) 3. Earnings	Both TQM elements significantly correlated with financial performance.

Paper	Sample	Method	Lean Practices	Performance outcome	Key findings
	European quality standards in the Turkish industrial area (manufacturing sector)				
Hong et al. (2014)	571 firms from 23 countries, between 28 and 35 on the two-digit ISIC code (manufacturing sector)	Structural Equation Modelling	1. Strategic customer-service orientation 2. Human lean practices 3. Technical lean practices	1. Sales 2. Market share	Customer focus and technical lean practices not correlated with performance. Correlation coefficients are positive and significant at 0.01 level for human lean practices-performance relationship.
Chavez et al. (2015)	228 manufacturing companies in the Republic of Ireland	Structural Equation Modelling and OLS regression	Internal Lean practices 1. Reduce setup time 2. JIT production Supplier partnership Customer relationship	1. Market share 2. Return on Investment 3. Growth of Market share 4. Growth of sales 5. Growth in ROI 6. Profit margin on sales 7. Overall competitive position	Significant and positive relationship between lean practices and performance.
Kumar and Kumar (2016)	62 Indian manufacturing plants	Correlation Analysis	Lean practices 1. Supplier participation 2. Operational initiatives 3. Employee participation 4. Customer participation	Financial performance	Excepting customer participation, all lean practices positively and significantly correlated with financial performance.

Appendix B. Sample data for analysis in first and second stages

Study	Study sample size (N)	Lean-Aggregate performance correlation (r)	Reliability of Lean practices (α_{xx})	Reliability of Aggregate performance (α_{yy})	Lean-Financial performance correlation (r_1)	Reliability of Financial Performance ($\alpha 1_{yy}$)	Lean-Market performance correlation (r_2)	Reliability of Market performance ($\alpha 2_{yy}$)
Das et al. (2000)	290	0.313	0.889	0.676	0.370	0.827	0.285	0.791
Brah et al. (2000)	176	0.182	0.846	0.802				
Curkovic et al. (2000)	57	0.165	0.826	0.821	0.137	0.827	0.222	0.791
Douglas and Judge (2001)	229	0.255	0.930	0.900				
Kaynak (2003)	214	0.212	0.863	0.890			0.212	0.890
Fuentes-Fuentes et al. (2004), (2006)	273	0.178	0.892	0.970	0.178	0.970		
Nahm et al. (2004)	224	0.343	0.847	0.870				
Ahmad et al. (2004)	86	0.153	0.865	0.863	0.139	0.863	0.167	0.863
Sánchez Rodríguez and Martínez Lorente (2004)	306	0.119	0.756	0.821	0.070	0.827	0.154	0.791
Brah and Chong (2004)	148	0.526	0.980	0.793				
Yeung et al. (2005)	225	0.258	0.870	0.744	0.114	0.730	0.144	0.758
Kannan and Tan (2005)	556	0.059	0.879	0.724	0.056	0.724	0.060	0.724
Swink et al. (2005)	57	0.410	0.848	0.720				
Christensen et al. (2005)	208	0.137	0.780	0.910			0.137	0.910
Lakhal et al. (2006)	92	0.113	0.807	0.821				
Avittathur and Swamidass (2007)	26	- 0.014	0.788	0.821	- 0.081	0.827	0.053	0.791
Jayaram et al. (2008)	57	0.113	0.636	0.952	0.113	0.952		
Agus (2008)	110	0.342	0.886	0.827	0.342	0.827		
Inman et al. (2011)	96	0.204	0.785	0.915	0.170	0.920	0.238	0.910
Agus and Hajinoor (2012)	200	0.302	0.896	0.935	0.297	0.827	0.317	0.791
Hofer et al. (2012)	229	0.183	0.827	1.000	0.140	1.000	0.205	1.000
Nawanir et al. (2013)	139	0.332	0.758	0.630	0.410	0.700	0.253	0.560
Laosirihongthong et al. (2013)	115	0.377	0.843	0.931				
Fullerton et al. (2014)	244	0.150	0.900	0.810				
Ghobakhloo and Hong (2014)	231	0.284	0.892	0.817	0.370	0.815	0.197	0.818
Akgün et al. (2014)	193	0.305	0.825	0.900	0.305	0.900		
Hong et al. (2014)	571	0.077	0.700	0.740			0.077	0.740
Chavez et al. (2015)	228	0.303	0.743	0.856				
Kumar and Kumar (2016)	62	0.365	0.794	0.707				

Appendix C. Sample data for analysis in third stage

Study	Study sample size (N)	Lean-Aggregate performance correlation (r)	Reliability of Lean practices (α_{xx})	Reliability of Aggregate performance (α_{yy})	Lean-Financial performance correlation (r_1)	Reliability of Financial performance ($\alpha 1_{yy}$)	Lean-Market performance correlation (r_2)	Reliability of Market performance ($\alpha 2_{yy}$)
Control Process & Improvements								
Brah et al. (2000)	176	0.124	0.817	0.802				
Curkovic et al. (2000)	57	0.192	0.832	0.821	0.196	0.827	0.185	0.791
Douglas and Judge (2001)	229	0.230	0.832	0.900				
Kaynak (2003)	214	0.256	0.780	0.890			0.256	0.890
Fuentes-Fuentes et al. (2004), (2006)	273	0.203	0.860	0.970	0.203	0.970		
Sánchez Rodríguez and Martínez Lorente (2004)	306	0.159	0.675	0.821	0.093	0.821	0.160	0.821
Yeung et al. (2005)	225	0.190	0.936	0.744	0.167	0.730	0.212	0.758
Swink et al. (2005)	57	0.320	0.850	0.720				
Agus (2008)	110	0.368	0.882	0.827	0.368	0.827		
Agus and Hajinoor (2012)	200	0.400	0.832	0.935	0.384	0.935	0.408	0.935
Nawanir et al. (2013)	139	0.385	0.760	0.630	0.480	0.700	0.290	0.560
Laosirihongthong et al. (2013)	115	0.296	0.808	0.931				
Ghobakhloo and Hong (2014)	231	0.422	0.901	0.817	0.514	0.815	0.330	0.818
Just-in-time flow								
Ahmad et al. (2004)	86	0.153	0.865	0.863	0.139	0.863	0.167	0.863
Kannan and Tan (2005)	556	0.040	0.866	0.724	0.036	0.724	0.041	0.724
Swink et al. (2005)	57	0.340	0.780	0.720				
Christensen et al. (2005)	208	0.107	0.820	0.910			0.107	0.910
Avittathur and Swamidass (2007)	26	0.057	0.788	0.821	- 0.050	0.827	0.164	0.791
Jayaram et al. (2008)	57	0.021	0.655	0.952	0.021	0.952		
Agus and Hajinoor (2012)	200	0.280	0.786	0.935	0.275	0.935	0.294	0.935
Nawanir et al. (2013)	139	0.288	0.746	0.630	0.358	0.700	0.218	0.560
Ghobakhloo and Hong (2014)	231	0.386	0.867	0.817	0.462	0.815	0.310	0.818
Chavez et al. (2015)	228	0.279	0.721	0.856				
Workforce development								
Brah et al. (2000)	176	0.208	0.842	0.802				
Curkovic et al. (2000)	57	0.144	0.824	0.821	0.114	0.827	0.204	0.791
Douglas and Judge (2001)	229	0.250	0.885	0.900				
Kaynak (2003)	214	0.174	0.905	0.890			0.174	0.890
Fuentes-Fuentes et al. (2004), (2006)	273	0.196	0.850	0.970	0.196	0.970		
Sánchez Rodríguez and Martínez Lorente (2004)	306	0.168	0.747	0.821	0.115	0.827	0.209	0.791
Yeung et al. (2005)	225	0.114	0.862	0.744	0.101	0.730	0.128	0.758
Swink et al. (2005)	57	0.640	0.870	0.720				
Lakhal et al. (2006)	92	0.080	0.795	0.821				
Agus (2008)	110	0.342	0.927	0.827	0.342	0.827		
Laosirihongthong et al. (2013)	115	0.395	0.899	0.931				
Ghobakhloo and Hong (2014)	231	0.259	0.892	0.817	0.340	0.815	0.177	0.818
Akgün et al. (2014)	193	0.290	0.830	0.900	0.290	0.900		
Hong et al. (2014)	571	0.113	0.700	0.740			0.113	0.740

Kumar and Kumar (2016)	62	0.403	0.765	0.707				
Maintenance Management								
Brah and Chong (2004)	148	0.526	0.980	0.793				
Nawanir et al. (2013)	139	0.360	0.700	0.630	0.480	0.700	0.240	0.560
Ghobakhloo and Hong (2014)	231	0.104	0.915	0.817	0.239	0.815	- 0.031	0.818
Customer focus								
Brah et al. (2000)	176	0.193	0.848	0.802				
Curkovic et al. (2000)	57	0.137	0.817	0.821	0.041	0.827	0.331	0.791
Douglas and Judge (2001)	229	0.310	0.885	0.900				
Fuentes-Fuentes et al. (2004), (2006)	273	0.245	0.850	0.970	0.245	0.970		
Nahm et al. (2004)	224	0.256	0.910	0.870				
Yeung et al. (2005)	225	0.127	0.840	0.744	0.112	0.730	0.141	0.758
Christensen et al. (2005)	208	0.204	0.720	0.910			0.204	0.910
Lakhal et al. (2006)	92	0.180	0.830	0.821				
Jayaram et al. (2008)	57	0.038	0.630	0.952	0.038	0.952		
Agus (2008)	110	0.315	0.854	0.827	0.315	0.827		
Laosirihongthong et al. (2013)	115	0.329	0.868	0.931				
Ghobakhloo and Hong (2014)	231	0.248	0.886	0.817	0.297	0.815	0.200	0.818
Akgün et al. (2014)	193	0.320	0.820	0.900	0.320	0.900		
Hong et al. (2014)	571	0.045	0.720	0.740			0.045	0.740
Chavez et al. (2015)	228	0.340	0.751	0.856				
Kumar and Kumar (2016)	62	0.224	0.848	0.707				
Supplier relationship								
Brah et al. (2000)	176	0.127	0.894	0.802				
Curkovic et al. (2000)	57	0.217	0.813	0.821	0.181	0.827	0.289	0.791
Kaynak (2003)	214	0.244	0.860	0.890			0.244	0.890
Nahm et al. (2004)	224	0.339	0.880	0.870				
Sánchez Rodríguez and Martínez Lorente (2004)	306	0.089	0.804	0.821	0.013	0.827	0.171	0.791
Yeung et al. (2005)	225	0.099	0.852	0.744	0.088	0.730	0.110	0.758
Kannan and Tan (2005)	556	0.042	0.892	0.724	0.077	0.724	0.025	0.724
Swink et al. (2005)	57	0.230	0.850	0.720				
Christensen et al. (2005)	208	0.101	0.800	0.910			0.101	0.910
Avittathur and Swamidass (2007)	26	-0.012	0.765	0.821	- 0.086	0.827	0.063	0.791
Jayaram et al. (2008)	57	0.119	0.630	0.952	0.119	0.952		
Agus (2008)	110	0.319	0.844	0.827	0.319	0.827		
Inman et al. (2011)	96	0.179	0.790	0.915	0.134	0.920	0.224	0.910
Hofer et al. (2012)	229	0.217	0.813	1.000	0.170	1.000	0.240	1.000
Nawanir et al. (2013)	139	0.465	0.870	0.630	0.530	0.700	0.400	0.560
Laosirihongthong et al. (2013)	115	0.488	0.795	0.931				
Chavez et al. (2015)	228	0.290	0.756	0.856				
Kumar and Kumar (2016)	62	0.419	0.728	0.707				

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Highlights:

- First meta-analysis relating main Lean Practices (LP) to Business Performance (BP).
- Positive effect of LP (r = 0.26) on aggregate BP (financial + market performance).
- No clear LP impact on individual financial results; impacts Commercial Performance.
- Only three of six analyzed LP (PC&I; WD; CF) have clear effects on BP.
- Country's level of economic development moderates LP-BP relationships.

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